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FOCUS

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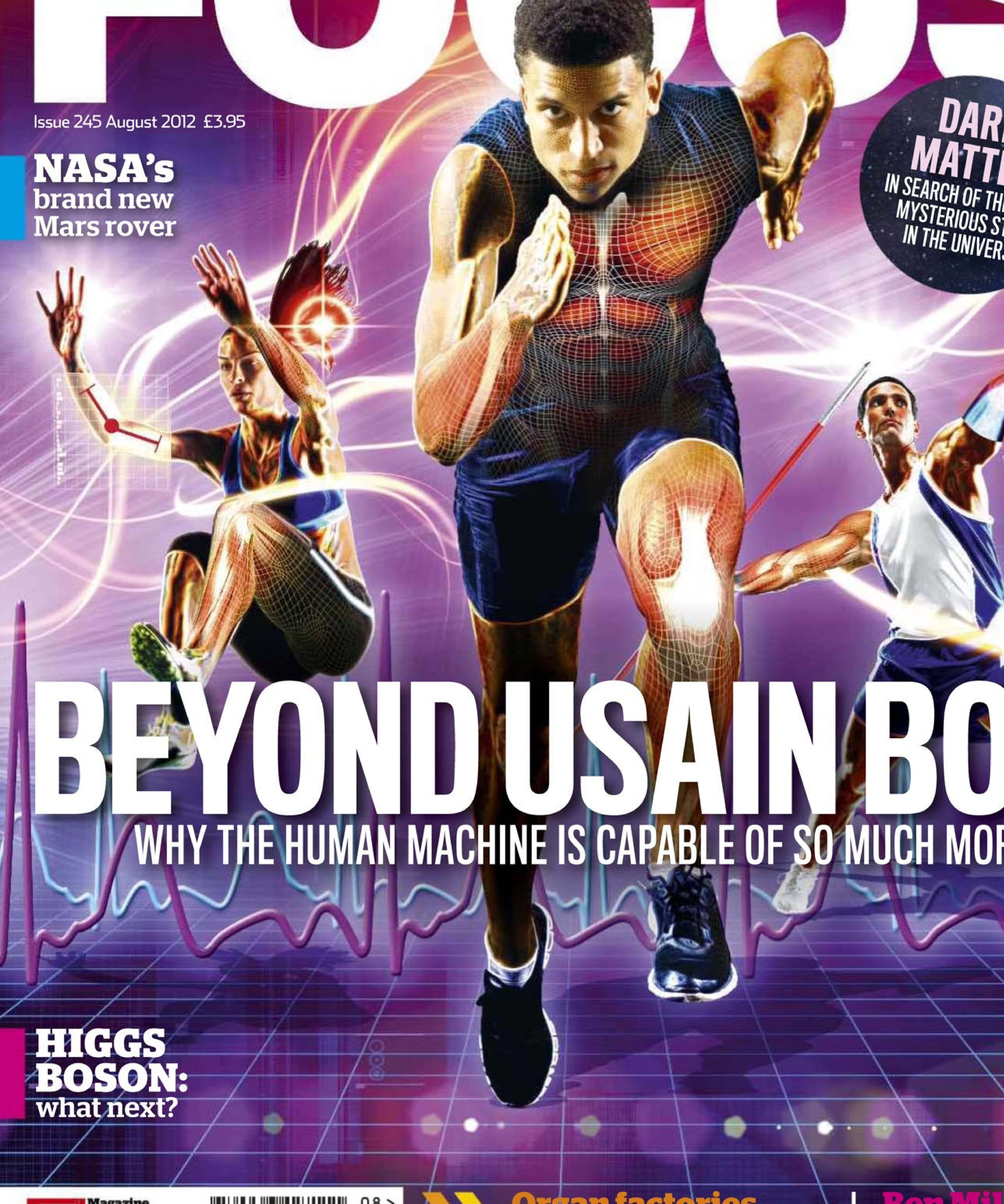

NASA's
brand new
Mars rover

DARK MATTER
IN SEARCH OF THE MOST MYSTERIOUS STUFF IN THE UNIVERSE

BEYOND USAIN BOLT

WHY THE HUMAN MACHINE IS CAPABLE OF SO MUCH MORE

HIGGS BOSON:
what next?

Magazine
ScienceFocus.com
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Organ factories
The medical labs that are growing human body parts to order

Ben Miller
The comedian tells us why he loves science

BEAUTY. SELDOM SEEN.

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Welcome

August 2012

SUBSCRIBE AND GET FOUR
FREE ISSUES OF *FOCUS* p32
Already a subscriber? On page 32 you'll find an exclusive feature on evolutionary biology

This month, over four billion people around the world are set to tune in to live TV coverage of a certain major sporting competition. If you're one of them, it's possible that you might see a world record or two bite the dust – that's usually the case at such events. But how long will this continue? In 2092, for instance, will the future equivalent of Usain Bolt be running the 100 metres in under six seconds? And what about swimming, or jumping? Top science writer Kate Ravilious investigates on page 34.

Sticking with the human body, we look at an area of cutting edge science that could have a profound impact on the future of human civilisation: replacement parts. If you need a new nose or leg, for instance, could you just grow a new one? Incredibly, scientists have already had some success in this sphere. They've produced livers, noses and bladders, and look set to grow even more body parts in the very near future, as you'll learn on page 64.

Just like growing body parts, the search for dark matter in the cosmos is right on the cutting edge of modern science. Astronomers believe dark matter exists, due to its gravitational influence on stars and galaxies, but they've never seen it. Now, a detector being constructed over 1.5km underground in South Dakota, USA represents perhaps our best hope of finding it. Find out why on page 42.

Sticking with space, a brand new rover is set to land on Mars this month – NASA's biggest and most ambitious to date. Take a look at its Earth-bound twin on page 56.

Cookery might seem far removed from Mars rovers and dark matter, but it's an area in which science is having an increasing impact, thanks to pioneering chefs such as Heston Blumenthal. In fact, the science of molecular gastronomy is 20 years old this month. So we've put together a mouth-watering feature about its past, present and future on page 48.

Besides all that, we spoke to comedian Ben Miller about his new science book (p62), looked at the latest tablet computers (p84) and tested electric bikes (p90).

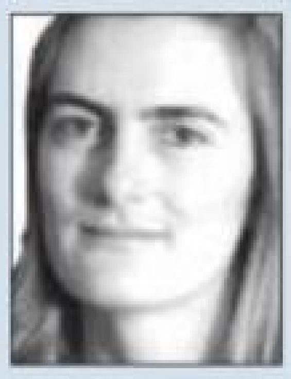
Enjoy the issue.

Graham

What I've found out this month

- Less than five per cent of the Universe is 'normal' matter (p42)
- Mango and carrot is scientifically proven to be tasty (p52)
- There's a prototype camera that can take 1 gigapixel pictures! (p22)

Experts

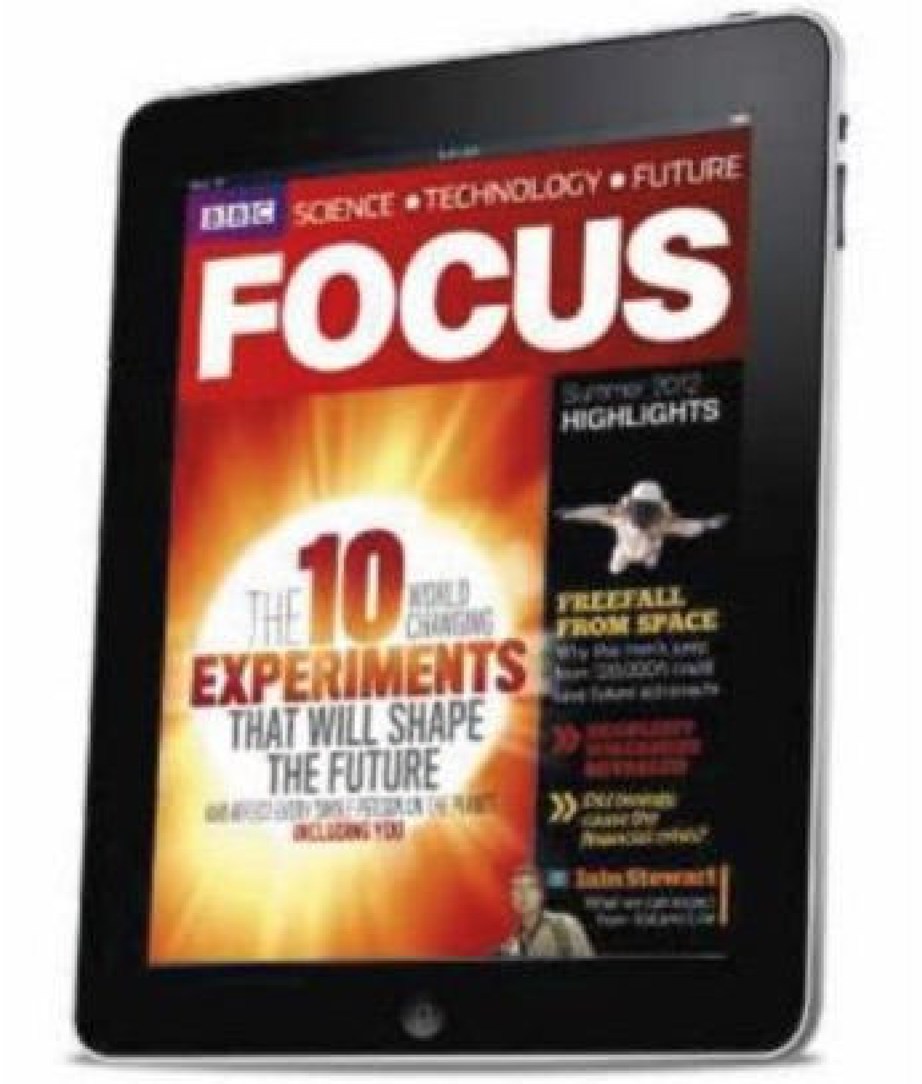


Kate Ravilious
Geologist Kate has been writing about science for magazines and broadsheets for over a decade. On page 34, she looks at how biology affects sporting performance, and what limits it imposes.

Emma Davies
Dr Davies was the perfect person to write our feature on molecular gastronomy, having an MSc in food science and a PhD in the chemistry of food colloids (one substance dispersed in another).

Paul Sutherland
Paul has had a distinguished career writing about all things astronomical. Not for nothing is he called 'The *Sun* Spaceman' by a certain tabloid newspaper! On p56, he looks at the latest Mars rover.

Ruth Williams
Dr Williams is a science and medical writer with a PhD in genetics. A former researcher in stem cell biology, she writes about growing body parts in the lab on p64.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FOCUS
Summer 2012 HIGHLIGHTS
THE 10 WORLD CHANGING EXPERIMENTS THAT WILL SHAPE THE FUTURE
FREEFALL FROM SPACE
Iain Stewart

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Exclusive to August's App:

- **Ben Miller talks about his love of science**
- **Meet the strangest ants on the planet**
- **A CERN scientist explains the Higgs discovery and its implications**

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August 2012

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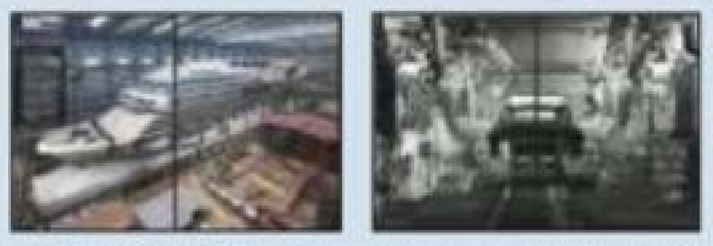

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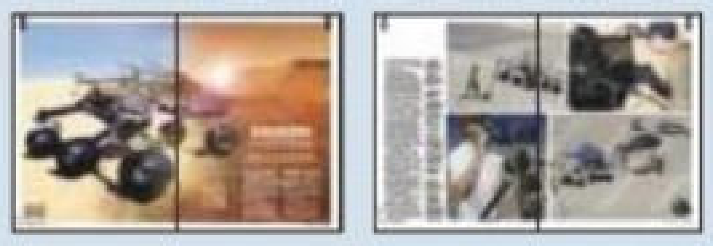

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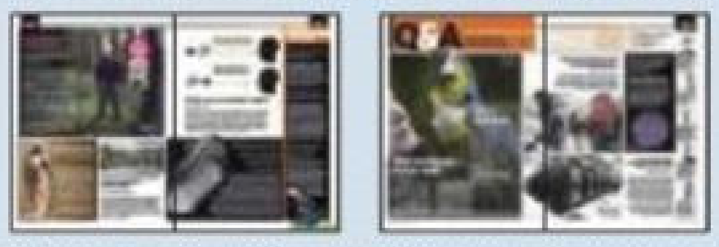

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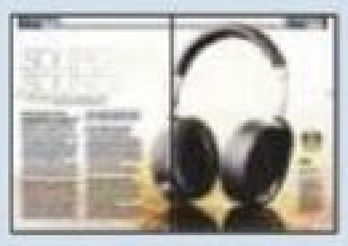

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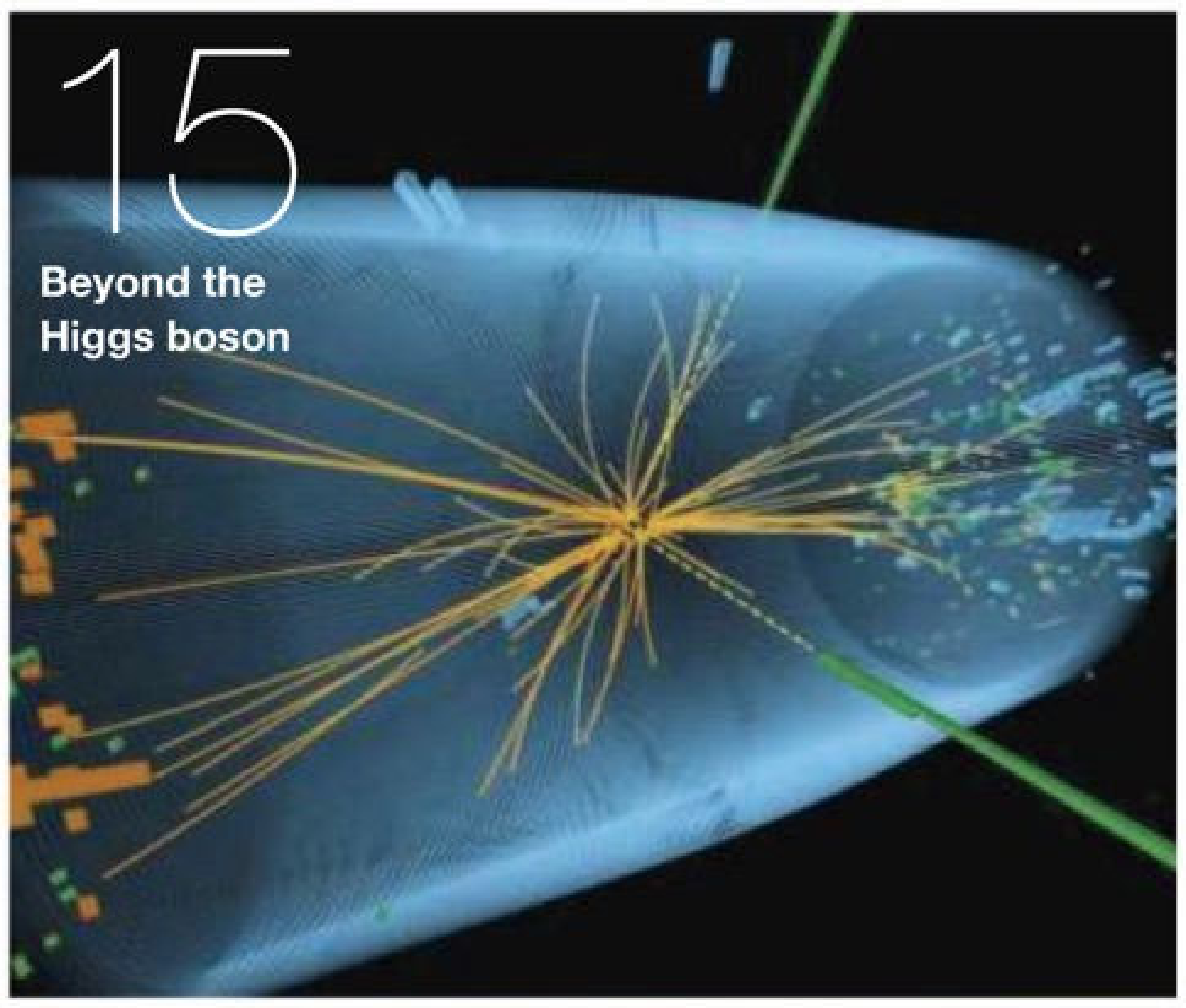

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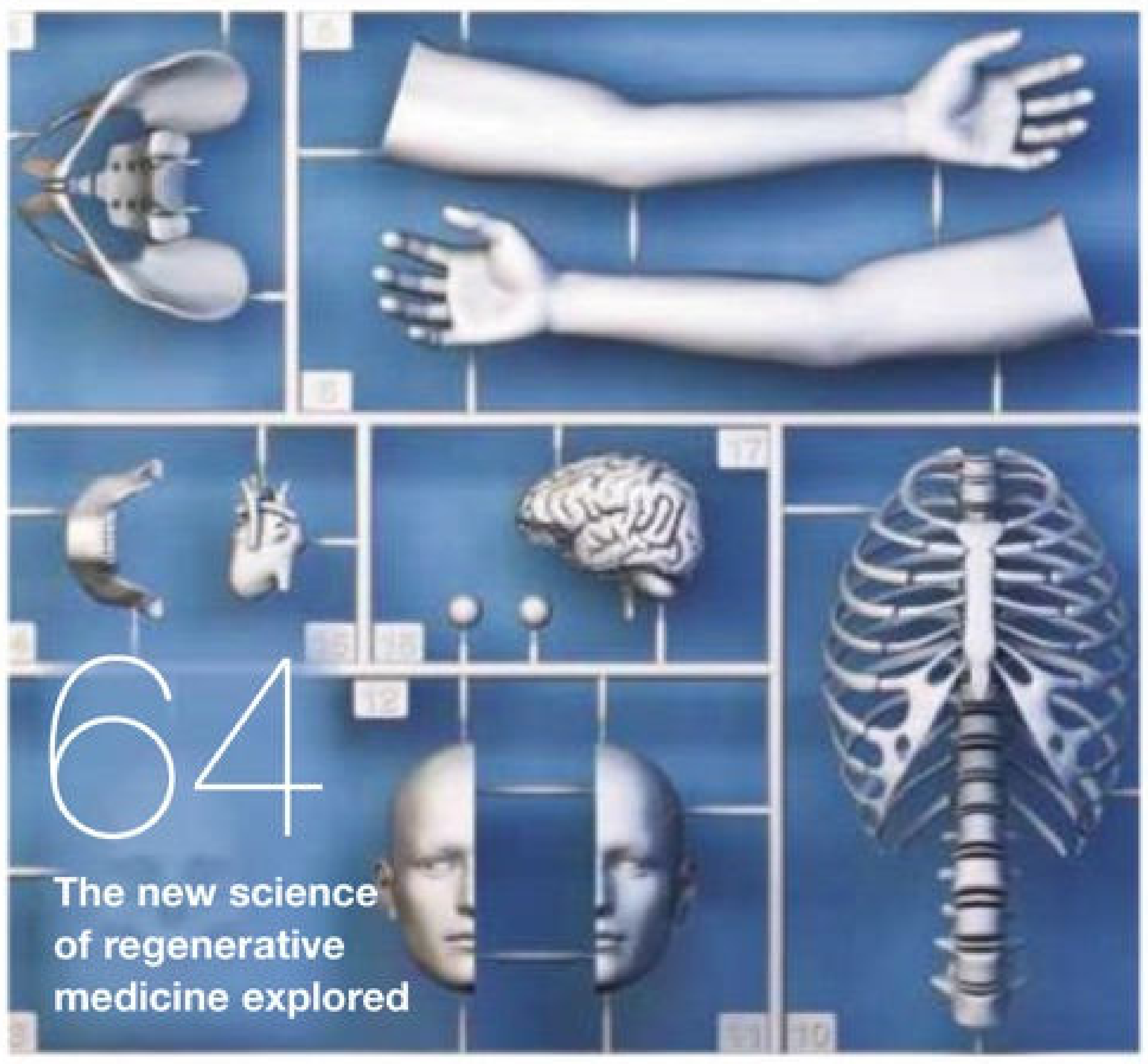

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PAUL PRICE, NASA, STUDIO4PHOTO, CORBIS, BROWN PARTICLE ASTROPHYSICS GROUP, CLAES BECH-POULSEN, MAGICTORCH

> *"We've got two noses growing, just in case someone drops one"*

Professor Alex Seifalian of UCL on his latest attempt to manufacture replacement organs in the laboratory. See *Grow your own body*, p64

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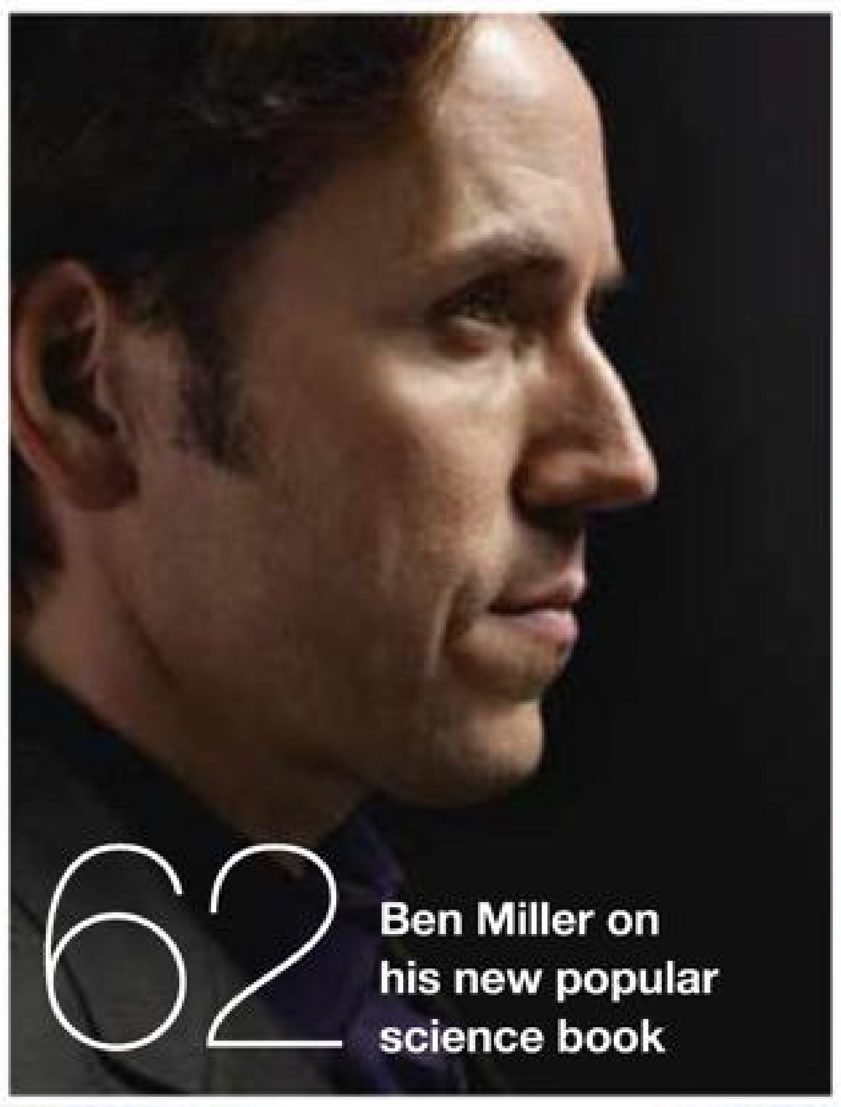

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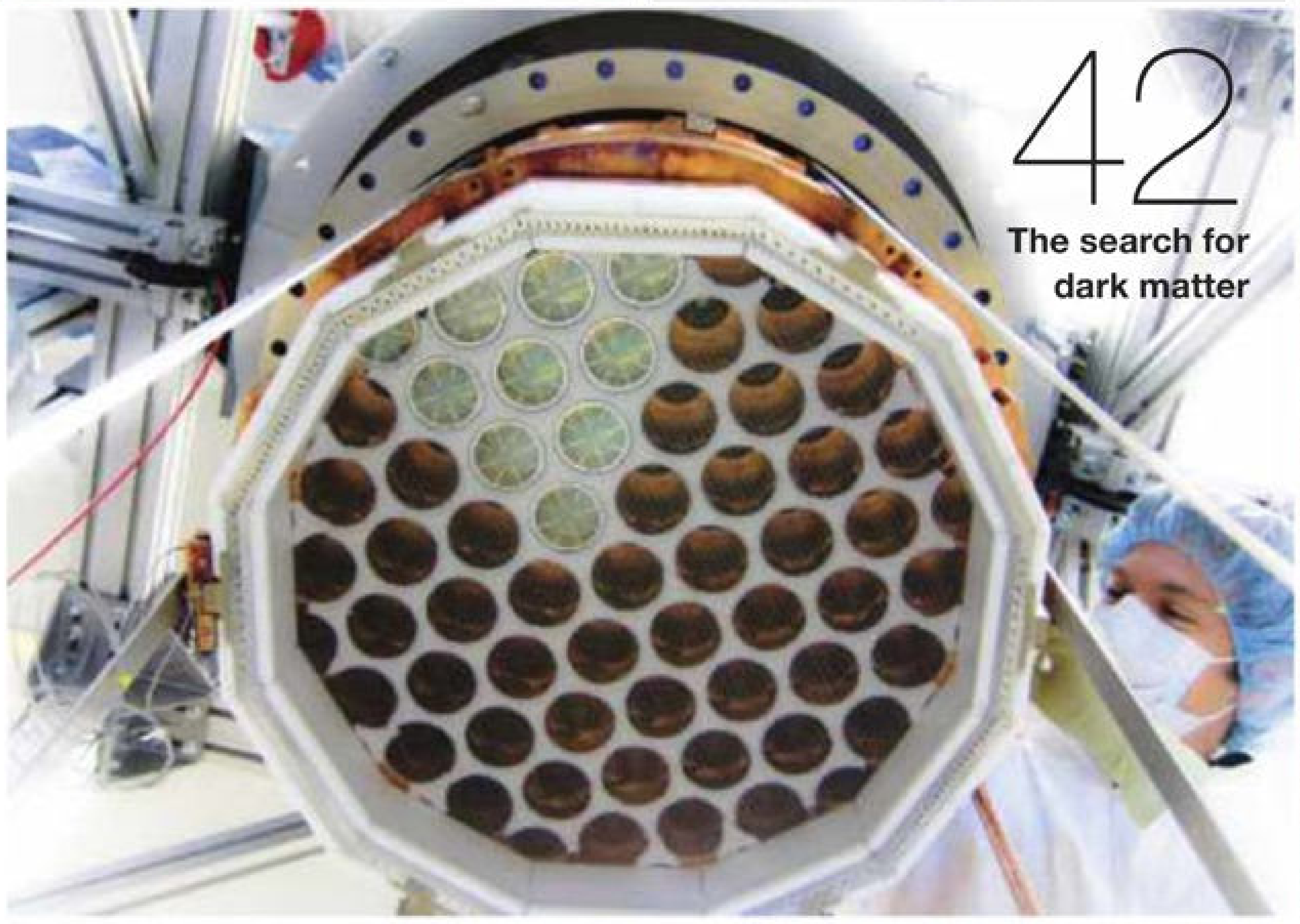
Ben Miller on his new popular science book



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Super size ships

Measuring 75m high, 125m wide and 504m (the length of five football pitches) long, this dry dock in the Meyer Werft shipyard is one of the largest roofed dry docks in the world. Located in Papenburg, northwest Germany and connected to the River Ems, this is where today's colossal cruise ships are built.

With cruise operators always wanting the latest features on their ships, the biggest challenge to building large vessels is the increasing complexity. "We have to improve our production facilities – not only to build ships bigger, but also to build them faster and more efficiently," says naval engineer Philip Gennotte, Meyer Werft's head of technical design.

The optimised production process begins long before a ship starts to take shape in the dock, where it's assembled from around 80 blocks. Each of these blocks consists of several sections of walls and deck stacked together and outfitted with pipes and cables to reduce construction time.

Once the ship is completed, the dock is flooded to allow it to sail out to sea.

MEYERWERFT

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STEINKA

JOHN STOCKLIN/TESLA

Spray safe

Tesla, the manufacturer of the world's first electric sports car, likes to do things differently. Its coating facility, seen here, uses uniquely tooled robotic spray guns that completely automate the painting of its new car, the Model S.

An extension added to each of the six robots enables the arms to open and close the doors, boot and bonnet without any human assistance. The small red dots you can just see either side of the car act as the robot's eyes.

"It's an insurance policy," says Tesla's Coating Centre Manager Mark Duchesne. "If any of the arms fail to close a door, then it will break the laser beam and stop the process so that none of the arms or doors collide."

MegaPixel

The dream factory

This snapshot is just one section of the enormous Boeing production facility in Everett, Washington. The rest of the 282-acre site is made up of 16 other structures like this, all of which are joined together to form the largest building, by volume, on the planet.

Some 33,500 workers populate the factory, which has its own medical clinic, fire department and water treatment plant. Its staff work in shifts 24 hours a day to produce around four of the 787 Dreamliners pictured per month.

"The factory never stops," says Boeing's Julie O'Donnell. "The planes enter the warehouse as a hollow shell, where the floors, hydraulics and electrical systems are fitted before moving down the production line. Its interiors, engine and power systems are then fitted in the next position and the final touches and production testing are completed in a spot just off the edge of this photo."

GETTY

DREAMLINER DINER
787
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787 787
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THE FUTURE SOUND OF LONDON

The PAL+ is old-fashioned cool for the digital age. It's small, portable and – in its new Limited Edition Union Jack design – a rather beautiful DAB radio. It will get flawless reception where many other radios won't and has a rechargeable NiMH battery, providing 10 hours play.

The PAL+ is weather-resistant, making it perfect for British summers. It's ready to go straight out of the box, and its 3.5mm aux input makes the PAL+ the perfect partner for any smartphone or MP3 player.

And, just in case that street party keeps you up late, it also features an auto set clock and dual alarms with snooze functionality.

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Update

The latest intelligence

Need to know

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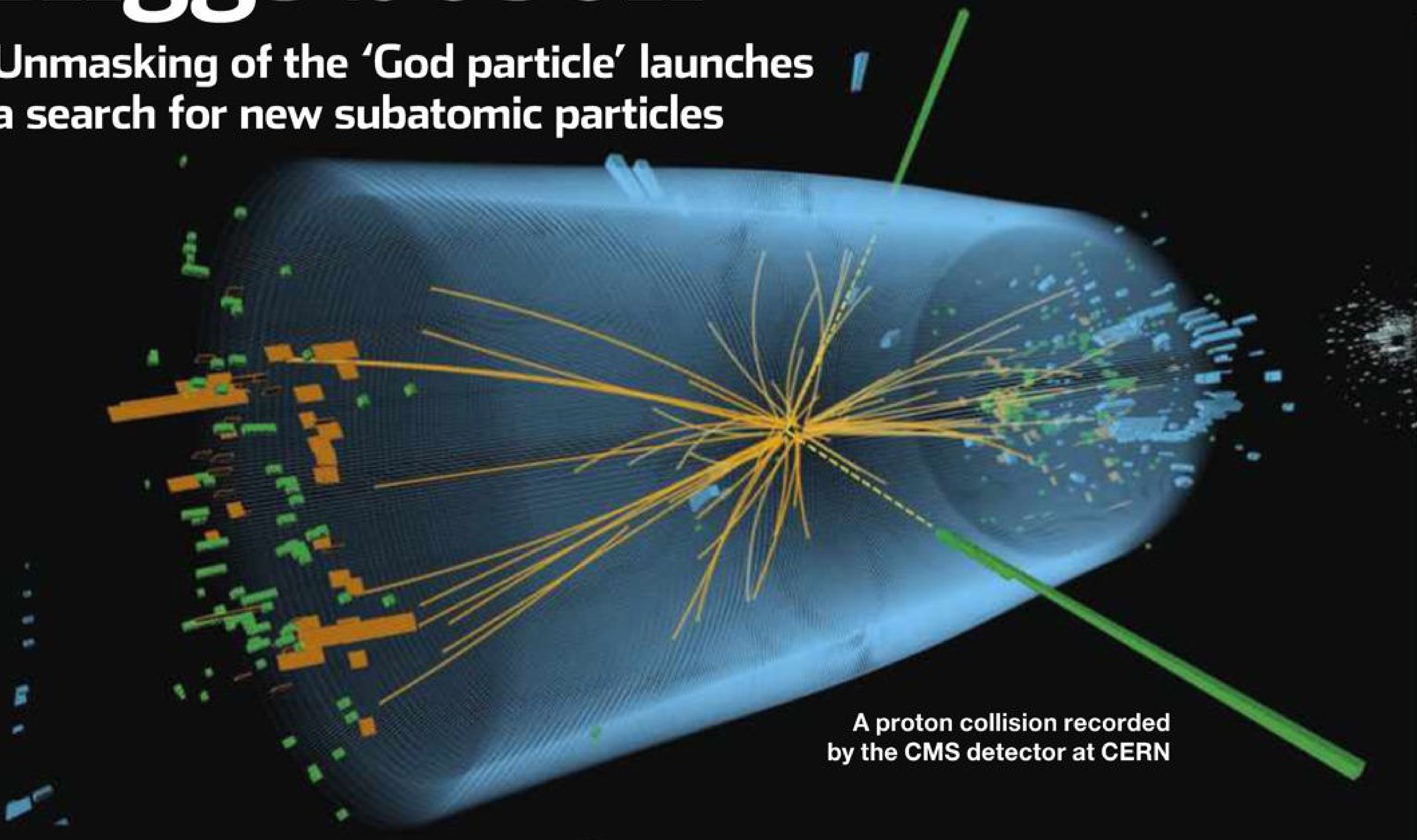
Found: the famous Higgs boson

Unmasking of the 'God particle' launches a search for new subatomic particles



A proton collision recorded by the CMS detector at CERN

Almost 50 years after its existence was first suggested, it appears that the Higgs boson has been found – an historic discovery that opens up whole new avenues of research for physicists.

Scientists at the Large Hadron Collider (LHC) particle smasher near Geneva say they have enough data to be confident they have discovered a new particle and that it looks distinctly like the elusive Higgs – but have stopped short of saying categorically that it is.

At the LHC, beams of protons have been racing around a 27km (16 mile) track before being smashed against one another in the hope that Higgs bosons will appear in the wreckage. But theorists predict they appear only fleetingly, quickly decaying to specific forms of subatomic particle. So rather than seeing Higgs particles themselves, physicists at two detectors at the LHC, CMS and ATLAS, say they've spotted decay products consistent with their having been created.

"We've seen this thing decay into Z bosons, photons and W bosons – all things you would expect with the Higgs," says Professor Andy Parker, a physicist at the University of Cambridge who works on ATLAS. But to be sure that what they have created is the Higgs, physicists say they want to see all the particles the Higgs is predicted to decay into – the 'decay modes'.

Over the coming months, many more protons will be sacrificed in the hope of seeing all these modes. "By the end of this year we should be able to see it in seven decay modes," says Parker. "If they all come out in the way one would expect, then you would be pretty confident it's a Standard Model Higgs."

The Standard Model is a theoretical framework that describes the Universe (see right). Using calculations from the Standard Model to predict the Higgs's mass gives a figure of infinity, which clearly can't be true. Another theory, supersymmetry, predicts that the Higgs interacts with corresponding 'supersymmetric' particles. It would give the Higgs a more reasonable mass.

"For this to work, the supersymmetric particles can't be far away from the Standard Model particles in terms of mass," says Parker. "So we should be able to produce them. This year's data and the higher energy data that will follow will give us a handle on whether the supersymmetry particles are there."

What is the Higgs boson?

Our best explanation for how the fundamental building blocks of the Universe – the elementary particles – behave is the Standard Model. It predicts that for these particles to have mass, they must be interacting with an invisible 'treacle', the Higgs field.

The smallest unit of the Higgs field is the Higgs boson. So the apparent discovery of the boson means we now know how particles have mass.

Physicist Peter Higgs, then working at the University of Edinburgh, proposed the particle in 1964 but he wasn't alone in the idea. Two other groups of researchers suggested similar theories that year too.

Peter Higgs: predicted the particle nearly 50 years ago

HUMAN ECOSYSTEM LAID BARE

Five-year research project reveals how our bodies are teeming with trillions of microbes – and how they keep us alive

The micro-organisms that live on and inside our bodies outnumber our own cells by a factor of 10 to one, the first detailed census of our 'ecosystem' has revealed. The Human Microbiome Project (HMP), whose results have just been announced, provides an insight into the role the bacteria, viruses and fungi we carry around with us play in maintaining our health.

Over the past five years, scientists working at some 80 institutions have been characterising the microbes that live with us. Their raw material was microbe samples taken from the bodies of over 240 healthy people – from inside their mouths and noses, their intestines and the skin behind their ears, among other places.

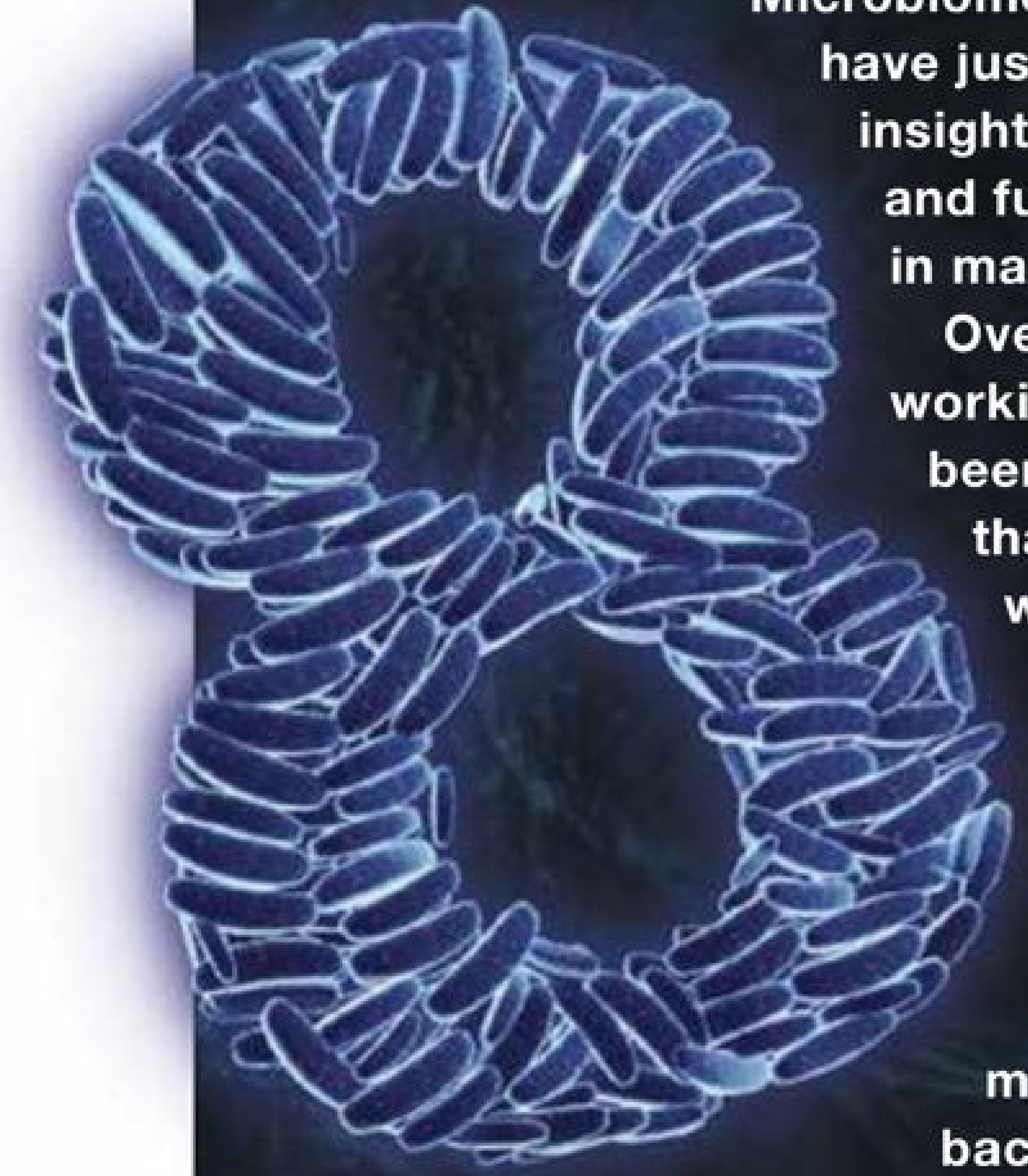
The vast majority of the microbes in our bodies are bacteria. By sequencing their DNA – a task only recently made practical by the speeding up of gene sequencing – scientists have obtained the clearest picture yet of how they interact with us. The $173 million project, largely funded by the US government, shows that more than 10,000 microbial species occupy the human body, and that each of us has our own unique collection.

"The range of variation we have found in the microbes in different individuals is tremendous," says Dr Dirk Gevers at the Broad Institute, who led the HMP research team. "It's surprising to find that we don't actually have a core set of common organisms, only a set of common functions."

Every one of us has, for instance, bacteria in our gut. These break down nutrients that would otherwise be unavailable to us, and produce important vitamins that our bodies are incapable of making. But the species that do this vary substantially from one individual to another.

Another surprise was that nearly everyone routinely carries pathogens – micro-organisms known to cause illness – on or inside their body. They are harmless most of the time, but one of the next research targets will be to establish why these bugs turn deadly.

It will also be important to learn more about the tasks the micro-organisms perform on our behalf when we're healthy.



million protein-coding genes have been found in the microbes that inhabit our body. This means there are 360 times more microbial genes exerting their effect on our body than human genes

77 per cent of bacterial families found in the nose have functions that are as yet unknown

of the body's mass is made up of microbes

microbe samples were taken from 242 adults, sourced from 15 body sites in men. In women, there were three further sample sites within the vagina

of people harbour *Staphylococcus aureus*, the bacteria which can cause MRSA, in their nasal passages – but this does not provoke symptoms in most healthy people

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Model shown is a new Kia cee'd 5-dr '4 Tech'.

Ant collection goes global

Entomologists from the USA have embarked on a mission to photograph every species of ant on the planet. Their aim is to create a vast online library of 3D images of the insects.

The scientists are visiting museums around the world to make sure they don't miss any of the 15,000 ant species that have so far been formally described by science. Their first port of call outside the US was the Natural History Museum in London.

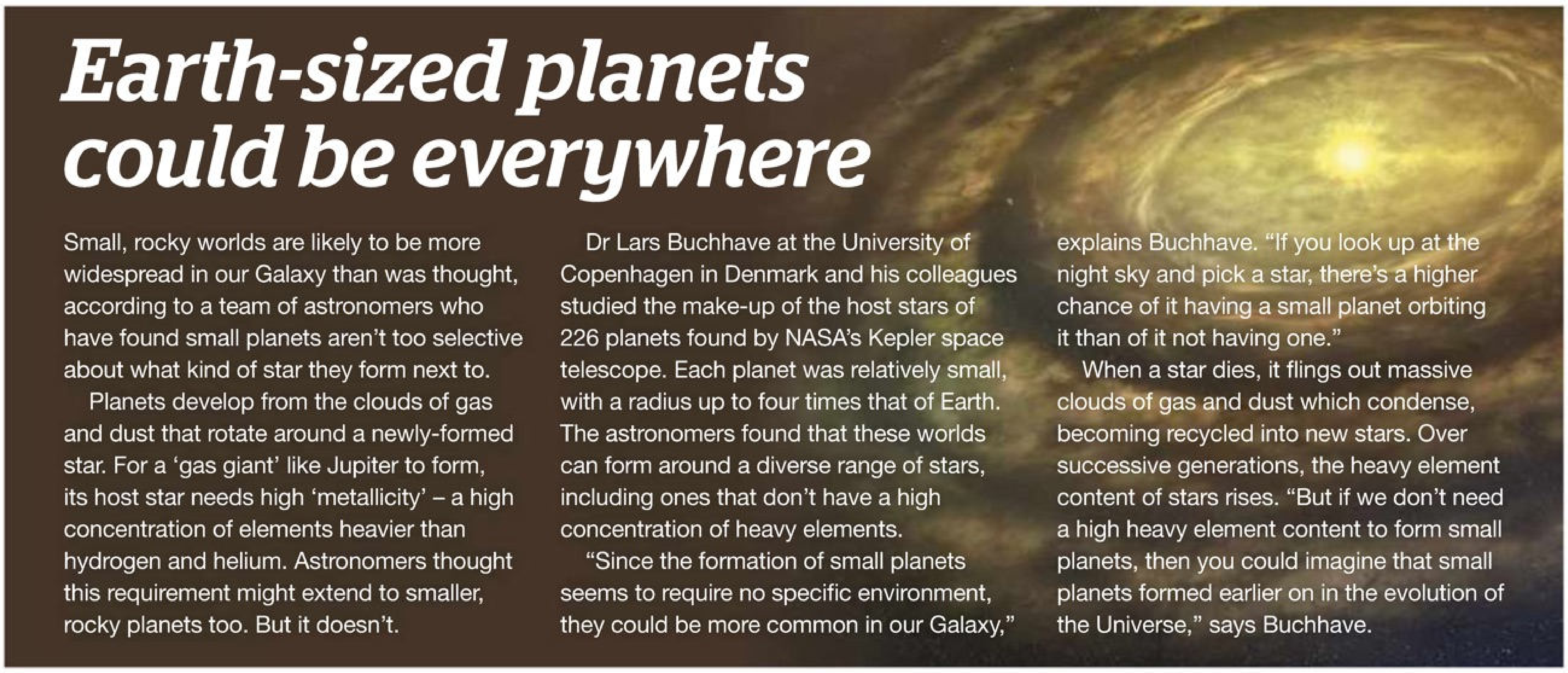
Paraponera clavata's sting is said to be as painful as being shot

"The 15,000 or so described species are our first priority," says Dr Brian Fisher from the California Academy of Sciences, who is leading the study. "But because we often see species in collections that have not yet been fully described, we image them, too. So by the end, we may have imaged 30,000 species."

To complicate matters, all the different castes – queens, soldiers and workers – and both sexes are being imaged for each species. To produce the 3D images, montages of up to 200 photos per specimen are stitched together.

"We're trying to save our field of science," says Fisher. "Nobody funds taxonomy or sees it as important. The old way of cataloguing specimens – one person sitting in their office for 30 years – is dead. We need to transform how we present our results to the public."

To get up close and personal with the 'bullet ant' (above) and his many equally photogenic relatives, visit **www.antweb.org**



Earth-sized planets could be everywhere

Small, rocky worlds are likely to be more widespread in our Galaxy than was thought, according to a team of astronomers who have found small planets aren't too selective about what kind of star they form next to.

Planets develop from the clouds of gas and dust that rotate around a newly-formed star. For a 'gas giant' like Jupiter to form, its host star needs high 'metallicity' – a high concentration of elements heavier than hydrogen and helium. Astronomers thought this requirement might extend to smaller, rocky planets too. But it doesn't.

Dr Lars Buchhave at the University of Copenhagen in Denmark and his colleagues studied the make-up of the host stars of 226 planets found by NASA's Kepler space telescope. Each planet was relatively small, with a radius up to four times that of Earth. The astronomers found that these worlds can form around a diverse range of stars, including ones that don't have a high concentration of heavy elements.

"Since the formation of small planets seems to require no specific environment, they could be more common in our Galaxy," explains Buchhave. "If you look up at the night sky and pick a star, there's a higher chance of it having a small planet orbiting it than of it not having one."

When a star dies, it flings out massive clouds of gas and dust which condense, becoming recycled into new stars. Over successive generations, the heavy element content of stars rises. "But if we don't need a high heavy element content to form small planets, then you could imagine that small planets formed earlier on in the evolution of the Universe," says Buchhave.

BRIAN L FISHER, MEDIAFARM/NIELS BOHR INSTITUTE

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INSIGHT

Ultimate blind spot mirror

What is it?
A mirror that eliminates your car's blind spot, without distorting what you see. The flat wing mirrors on cars have a narrow field of view, so there's a region behind the car that drivers can't see – the blind spot. One solution is to buy a curved mirror that sits over the original wing mirror and widens the field of view, but these distort the view, making cars appear smaller and further away. But now Prof Andrew Hicks, a mathematician at Drexel University in Philadelphia, has come up with a solution.

How does it work?
Hicks's mirror is made up of many smaller ones turned to different angles, like a disco ball. He's come up with an algorithm that controls the angle of each of these smaller mirrors so that, overall, they provide the driver with a wide field of view – 45° compared to the 15-20° of standard wing mirrors – that's not distorted.

Does it look like a disco ball?
Fortunately not. But it is wavy, its curvature changing microscopically at different points. It's only recently that it's become possible to produce such a complex surface.

When will the mirror go on sale?
Hicks came up with the idea a while ago, publishing a research paper in 2008. For the past decade he's been perfecting the design, and he now has a patent. Manufacturers have shown an interest in producing the mirror, so we might see one soon.

Hicks's mirror is made up of many smaller mirrors, all at different angles

ROUND UP

This month's top science stories from around the globe

PHYSICS

Shining light on masterpieces

A new optical technique is helping researchers unlock hidden details of Renaissance paintings. By illuminating the paintings with mid-infrared radiation and then detecting the reflected light using a camera, scientists in Italy spotted features that were invisible to both the naked eye and pre-existing imaging techniques. Analysis of *The Resurrection* by Piero della Francesca revealed that an area around a soldier's sword had been repainted using two different fresco techniques.

ENVIRONMENT

Seafloor to produce power

Inspired by the way in which muddy seafloors absorb energy from waves, an engineer at the University of California, Berkeley has come up with a novel idea for harvesting the sea's energy. Prof Mohammad-Reza Alam has proposed a device consisting of a 'viscoelastic carpet' placed over a network of springs and generators on the seafloor. A wave passing overhead would create ripples in the carpet's surface, which could be used to generate electricity. The carpet would be resistant to storms.

PHYSIOLOGY

Shrimp inspires armour

The secrets of the mantis shrimp's club, which it uses to bludgeon its prey, have been discovered by analysing its microscopic structure. Hydroxyapatite crystals, also found in human bones, have been found to be arranged in columns perpendicular to the surface, providing a great deal of compressive strength. The club's internal structure also prevents cracks from spreading. By mimicking this structure, scientists hope to develop tougher medical implants and body armour.

PSYCHOLOGY

Shoes speak volumes

Don't judge a book by its cover – but do judge a person by their shoes. US psychologists have shown that people can make good estimates of age, gender, income and even personality traits based on footwear alone. Researchers showed people photos of volunteers' shoes and asked them to assess their owners. While some of the connections were obvious, such as colourful shoes being worn by extroverts, others were less so, such as ankle boots being worn by aggressive types.

SPACE

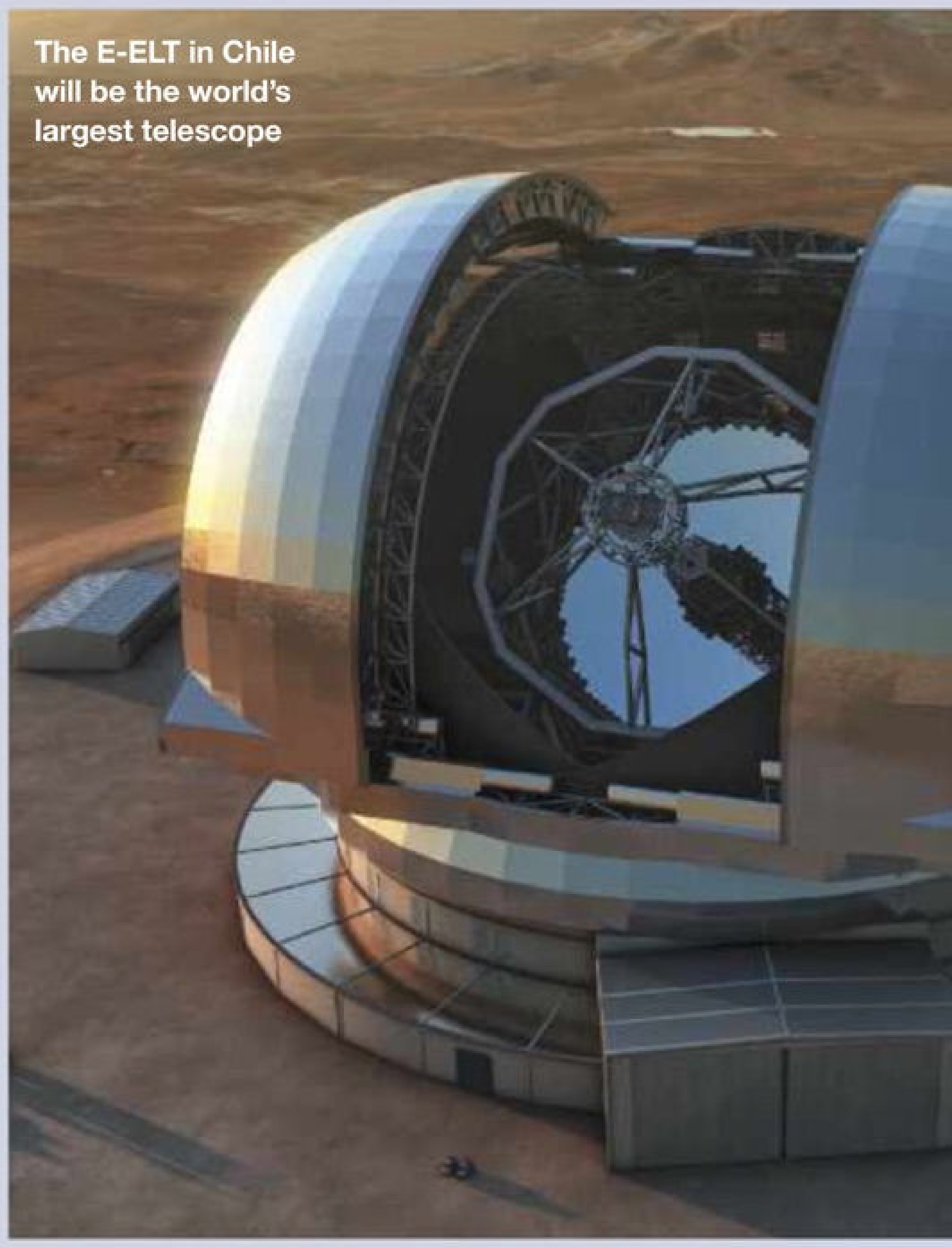
Super scope approved

A new telescope to be built on a mountain in Chile will allow astronomers to peer further back in time than they can with any other ground-based scope. The European Extremely Large Telescope (E-ELT), which has now been approved for construction by the European Southern Observatory, will boast a 39m-diameter segmented mirror that will gather 13 times more light than today's biggest optical telescope. This will allow the earliest galaxies to be studied in greater detail.

NEUROSCIENCE

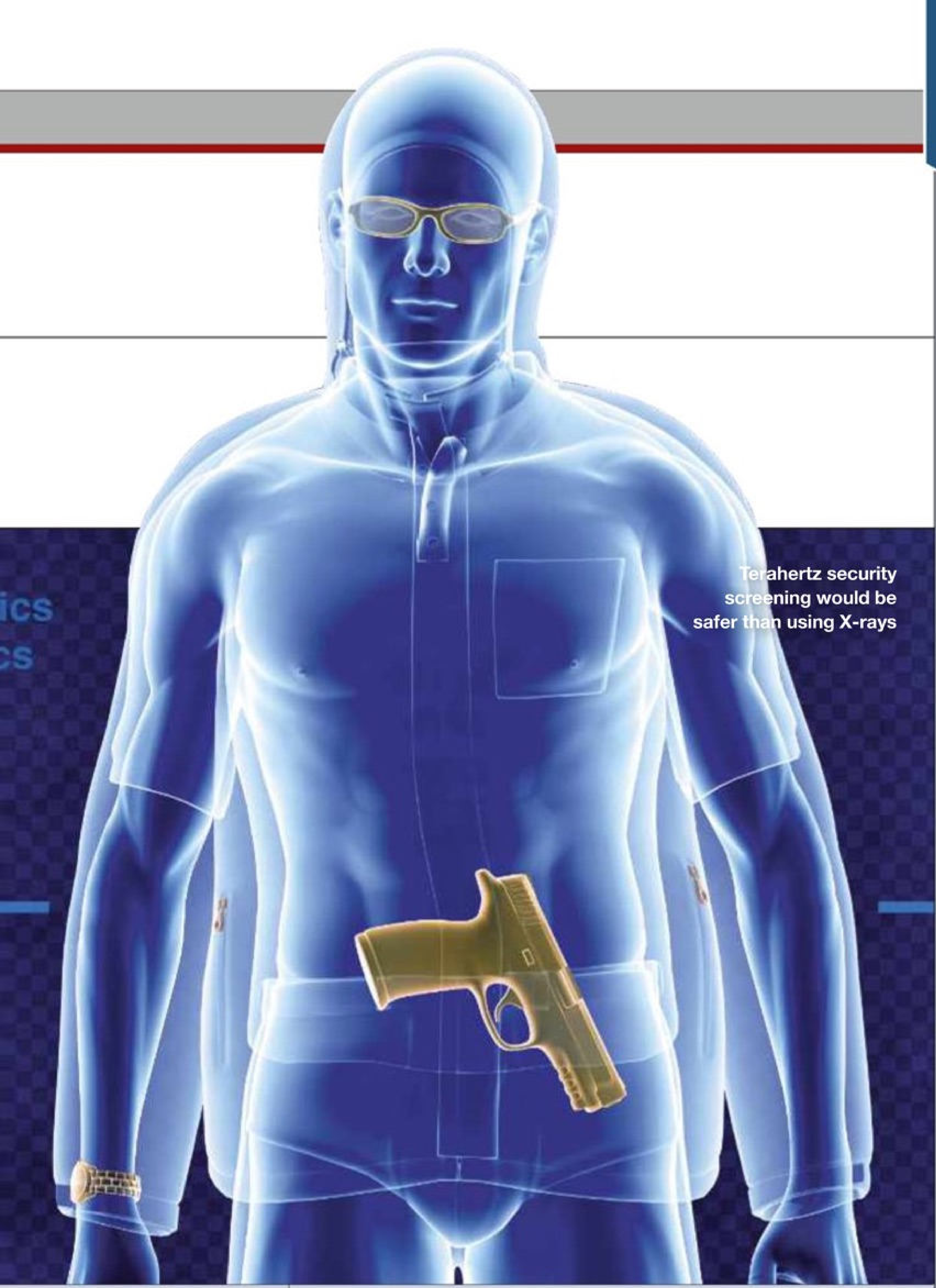
Hawking's mind hacked

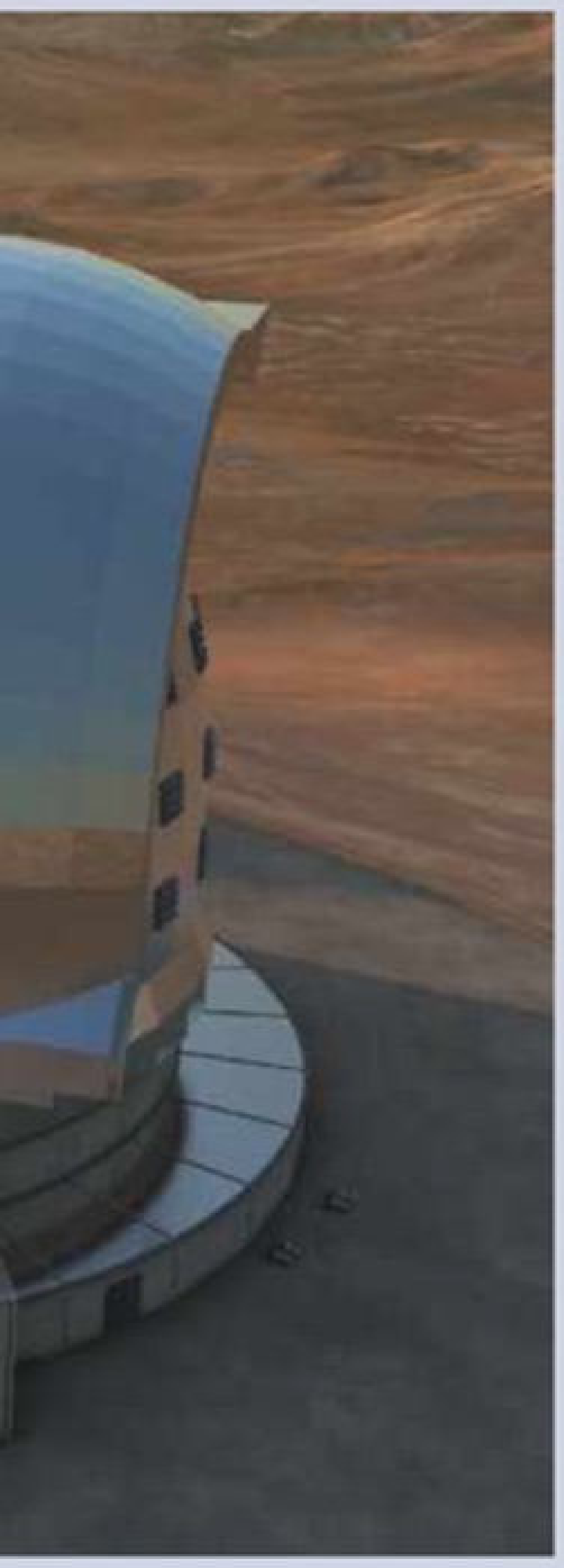
A device is being developed which may eventually be able to read Stephen Hawking's mind. The physicist has motor neurone disease and lost the power of speech nearly 30 years ago. He is working with Dr Stephen Low, who runs a company called NeuroVigil in the US and is developing iBrain, technology that can measure the brain's electrical activity. So far, Hawking has been able to create specific patterns of brain impulses by imagining using his hands and limbs. The long-term goal is to link many such intended movements to words.



The E-ELT in Chile will be the world's largest telescope

ISTOCKPHOTO, QUEENSLAND UNIVERSITY OF TECHNOLOGY, ESO, R ANDREW HICKS/DREXEL UNIVERSITY


Terahertz security screening would be safer than using X-rays



TECHNOLOGY

Terahertz radiation powers up

A safer alternative to medical X-rays and existing security screening is on the horizon thanks to a new way of generating terahertz radiation. Sitting between infrared and microwave radiation on the electromagnetic spectrum, terahertz radiation can penetrate clothing and several millimetres of tissue, but with a lower, less damaging energy than X-rays. Engineers at New York's Cornell University have now developed a semiconductor-based terahertz source that is 10,000 times more powerful than previous ones – a step towards using this radiation in everyday devices.

HEALTH

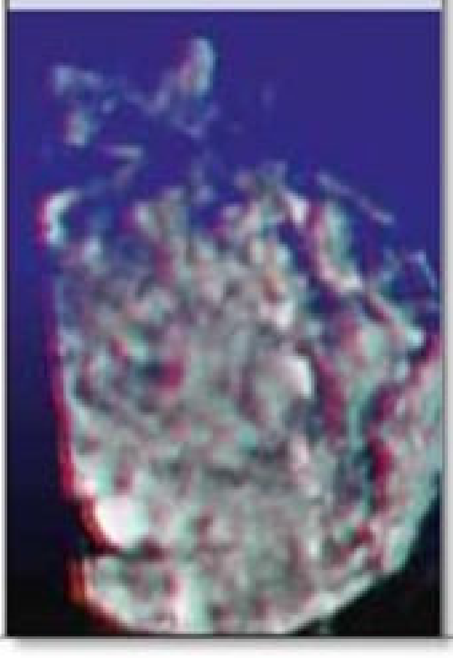
Foetal genome sequenced

A non-invasive way to reconstruct the entire DNA sequence of a foetus using only blood from the mother and saliva from the father has been developed – an advance that could one day allow routine scanning for defects long before birth. A pregnant mother's blood contains fragments of DNA from both her genome and that of her unborn child. The key is determining which DNA comes from the child. Fragments that contain gene variants found in the father's DNA, but not the mother's, must have come from the foetus. These fragments can then be screened for defects.

FLOATING LUNAR SOIL EXPLAINED

The source of the strange properties exhibited by soil on the Moon may have been discovered. Electrostatically charged, it can hover above the Moon's surface. It is highly chemically active as well as wearing the surface off metal and glass. Now soil scientist Dr Marek Zbik at Queensland University of Technology in Australia has analysed the soil's structure using a new microscopy technique and found tiny 'nano particles' inside tiny bubbles of glass in lunar soil. It is thought these particles first form in bubbles of molten rock when a meteorite hits the lunar surface, with a subsequent hit releasing the nano particles inside. Zbik says the particles behave according to the laws of quantum physics, accounting for the soil's unusual behaviour.

Nano particles in lunar soil give it some rather odd properties



NEWS IN BRIEF

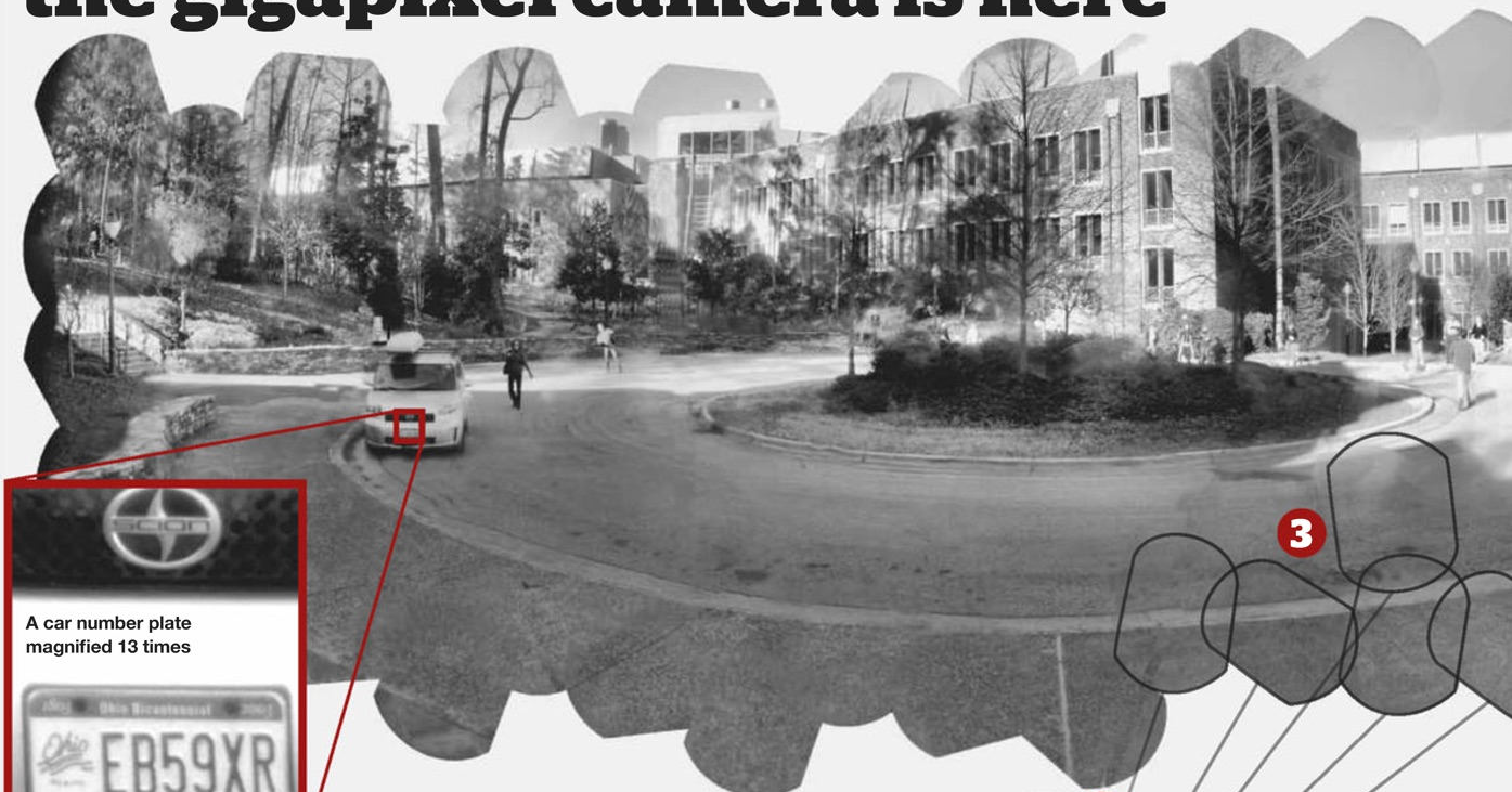
How do mosquitoes survive an impact with a raindrop? By rolling with the blows. Biologists at Georgia Institute of Technology in Atlanta decided to investigate how the tiny insects can fly through rain – after all, mosquitoes are typically 3mm long and weigh about 2mg, whereas raindrops are 2-8mm in diameter and can weigh up to 100mg. The team found that mozzies combine with a raindrop, falling with it by up to 20 body lengths. They then separate from it and continue flying.

Thousands of 'super tornadoes' over 5,500km (3,400 miles) wide may be responsible for the fact that the Sun's outer atmosphere is far hotter than its surface. Our star's surface is about 5,500°C whereas its outer atmosphere, or corona, reaches two million degrees. Using NASA's Solar Dynamics Observatory, astrophysicists detected hot plasma in the corona at the same location as the tornadoes. It's thought these structures transport energy from the surface to the corona.

A private non-profit organisation hopes to launch an asteroid-hunting telescope later this decade. The B612 Foundation in California wants to send an infrared telescope on a Venus-like orbit around the Sun. Its aim would be to spot 90 per cent of the asteroids larger than 140m across and "a significant number" down to 30m. Donations are being sought to meet the cost, which will be several hundred million dollars.

The latest volcano-monitoring technology, including the European Space Agency's Sentinel satellites due to be launched next year, will be used to improve forecasts of future eruptions at six volcanoes. It's part of a £3 million project aimed at reducing the threat they pose. Survivors of past eruptions will also be interviewed as part of the research, which is being led by the University of East Anglia and will focus on volcanoes in Latin America and the Caribbean.

Forget megapixels, **the gigapixel camera is here**



A car number plate magnified 13 times

While today's consumer cameras typically muster less than 20 megapixels, a model developed in the US is taking one-gigapixel images – that's 1,000 megapixels, or one billion pixels. AWARE-2 is packed with 98 microcameras, each of which takes a 14-megapixel image. These are then stitched together to produce the gigapixel photo.

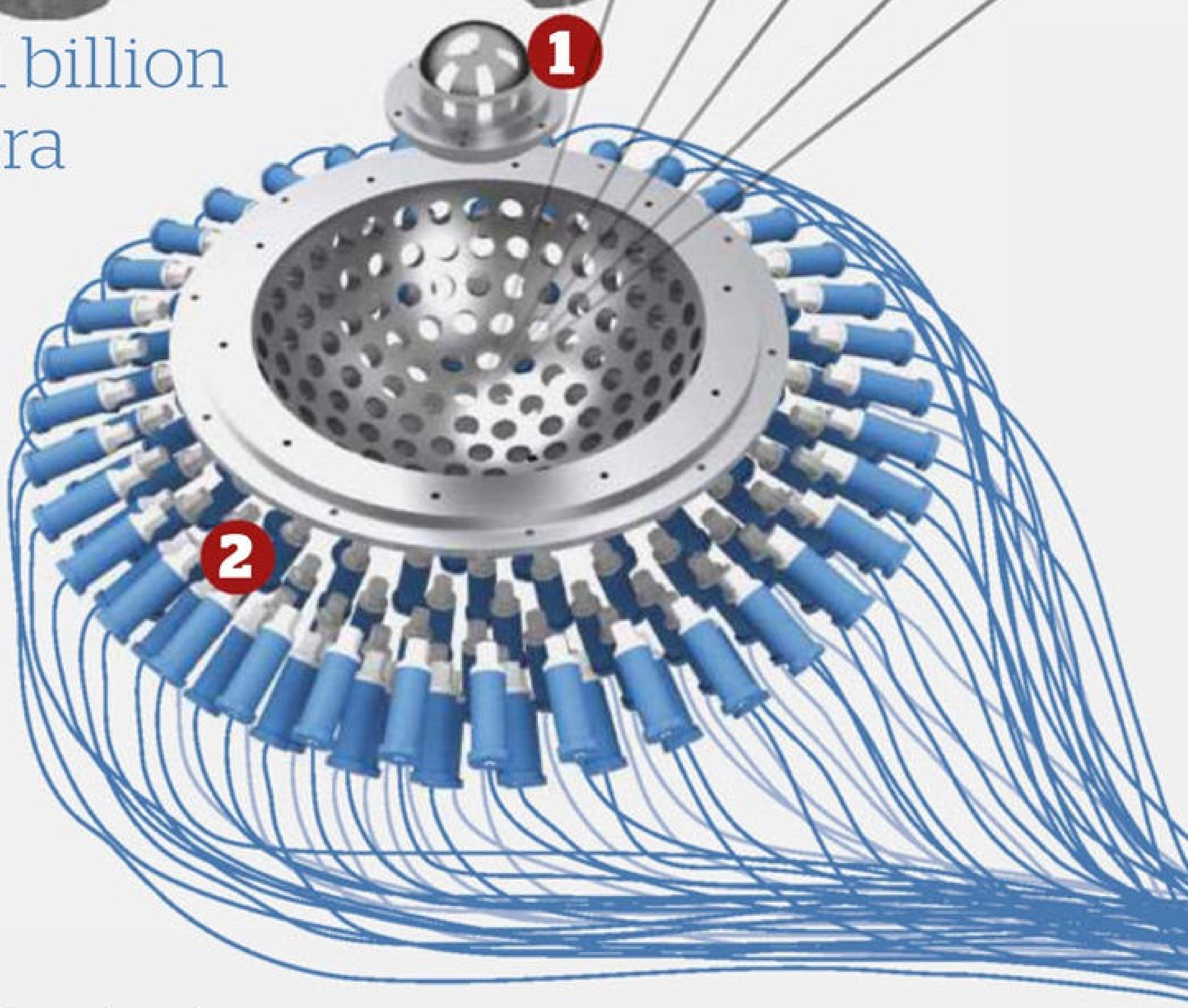
AWARE-2 isn't the first gigapixel camera, but it has one big advantage. The technology has the potential to be scaled down to portable dimensions. The prototype, which has been developed by several US institutions including Duke University, North Carolina, is pretty bulky – roughly the same size as a TV camera. But the developers believe that over the next five years, the components can be shrunk considerably.

At one gigapixel, the camera's resolution is five times better than 20/20 human vision. "The camera can capture images of things that photographers cannot see themselves, but can then detect when the image is viewed later," says Professor David Brady at Duke.

The camera, funded by the Defense Advanced Research Projects Agency (DARPA), can accommodate up to 220 microcameras, pushing the resolution up to 50 gigapixels, or 50,000 megapixels. And it won't just be available to military types, either.

"We're talking to media companies about the possibility of using this kind of camera to record sporting events," says Brady. Online shots of significant moments would be posted online and allow viewers to zoom in to a specific part of the action.

Inside the 1 billion pixel camera



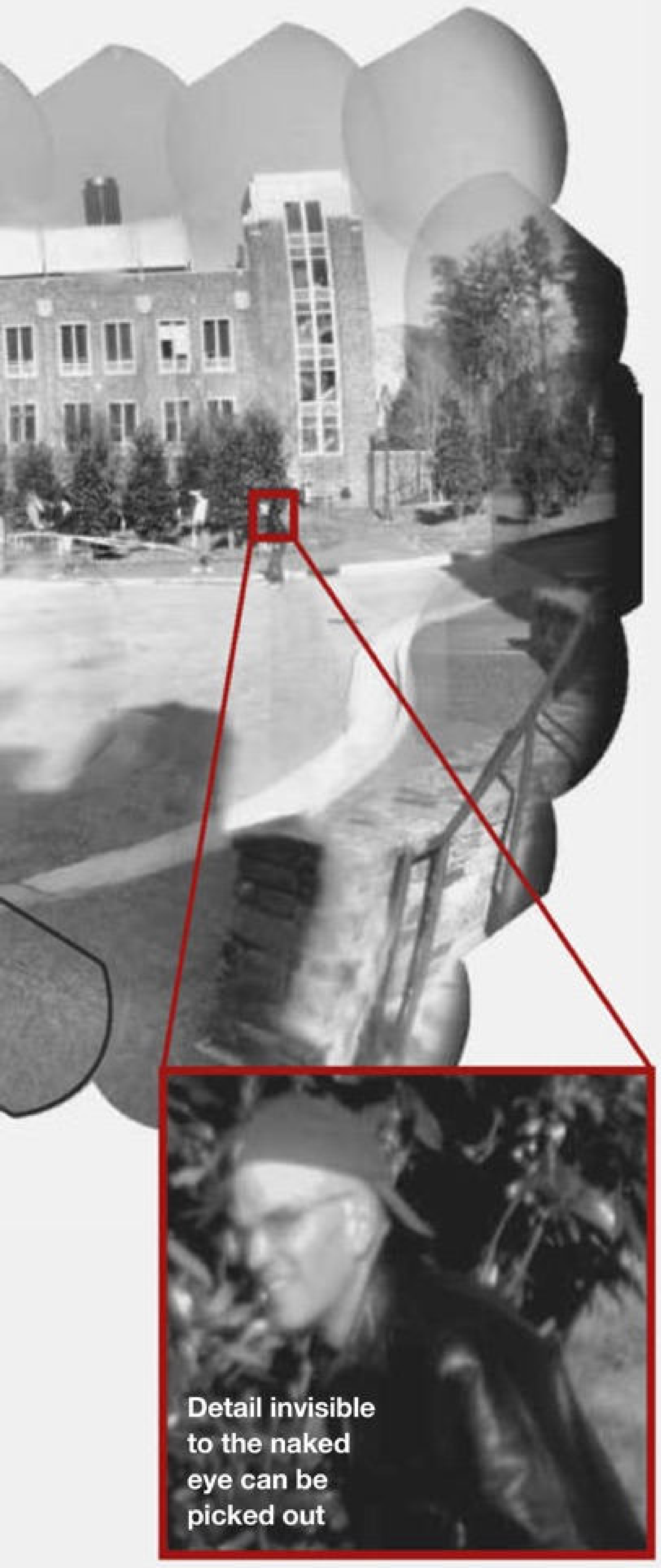
1 An objective lens gathers light from a 120° field of view, routing it to 98 microcameras.

2 Microcameras are fixed into an aluminium dome. They capture a specific area of the field of view using 14-megapixel sensors.

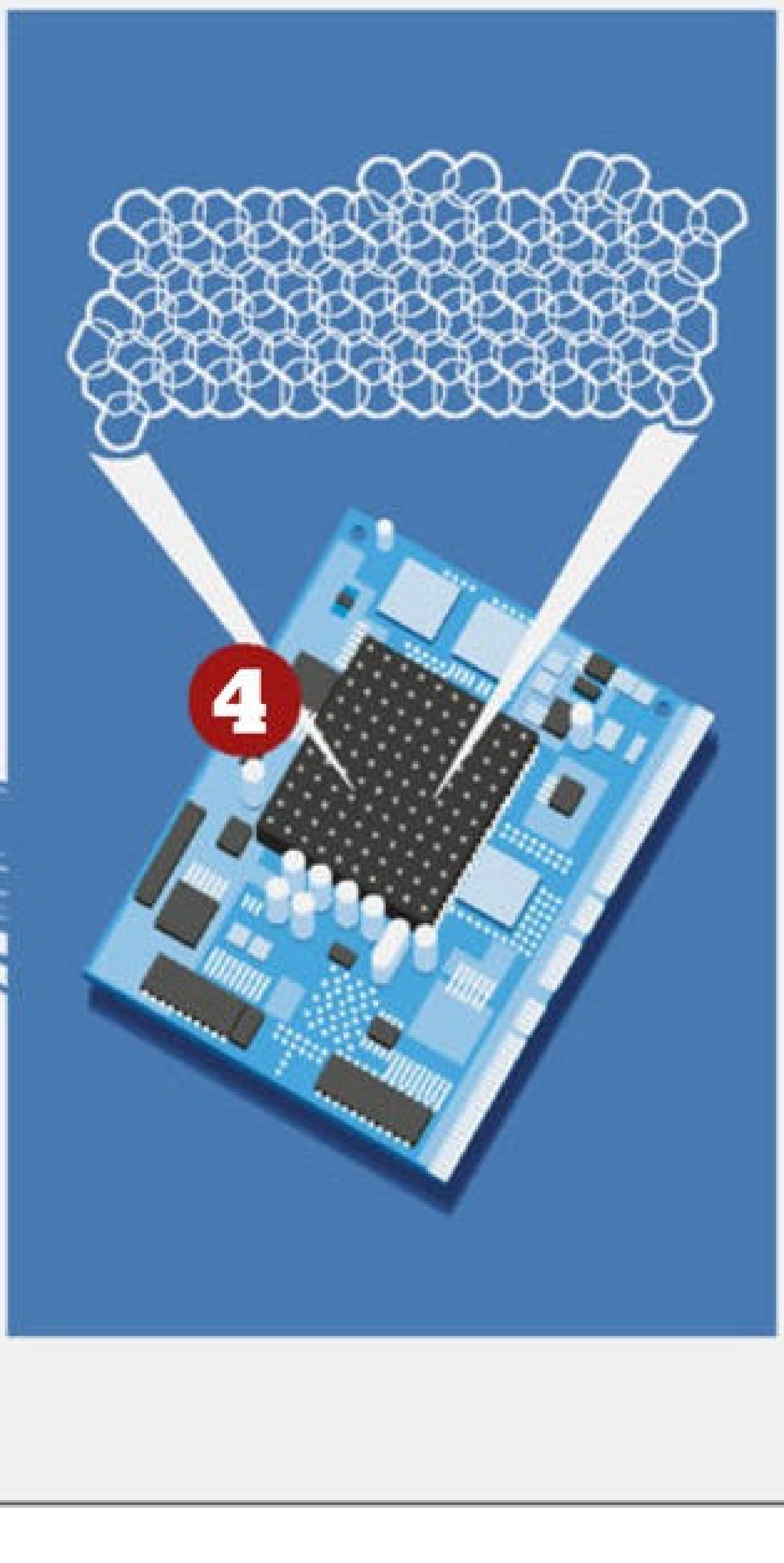
3 A small amount of overlap between the images captured by each camera ensures that nothing is missed.

4 The images captured by each camera are fed into a computer, where a 'compositing algorithm' stitches them into a seamless photo containing one billion pixels. No fewer than 84 processing units are required to crunch through the data.

PEDRO SAURA, ILLUSTRATION BY PAUL WESTON



Detail invisible to the naked eye can be picked out



Tree rings reveal radiation burst

A study of trees that were growing over 1,000 years ago has revealed that an intense burst of radiation hit the Earth in around 775AD. But what caused it is far from clear.

Researchers at Nagoya University in Japan measured the amount of carbon-14 (C-14) in Japanese cedar trees. C-14 is a radioactive isotope produced when radiation from space hits atoms in the atmosphere, producing neutrons. These then hit nitrogen-14, which decays to C-14. Tree rings that grew just over 1,200 years ago show a 1.2 per cent rise in C-14 – around 20 times greater than the typical variations.

Only two known events could cause the level of radiation required for such a spike. One is a supernova explosion, the explosion of a star, and the other is a proton storm from a powerful solar 'superflare' in which large amounts of energy are released from a star. But a bright supernova would have been visible in the night sky as a 'new star' and there are no recorded sightings for 775AD. Even if the supernova went unnoticed, we should be able to detect its remnant today using X-ray telescopes, but no corresponding object has been observed. Similarly, a proton storm from the Sun should have left its mark. It is believed that such an intense event would destroy the ozone layer, causing a mass extinction. But one avenue of research is to investigate the possibility of a non-destructive superflare.

Cedar tree rings pinpoint astronomical event

Ancient artistic whodunnit

Neanderthals may have been responsible for what is now considered Europe's oldest cave art. Previously there had been little evidence that Neanderthals decorated their caves. But experts at Sheffield and Bristol universities, with colleagues from Spain, now believe a red disc in the El Castillo Cave in northern Spain was drawn at least 40,800 years ago. At that time, Neanderthals were living in Spain, and modern humans were only just entering Europe from Africa. The researchers obtained an approximate age for the art by determining the age of the calcium carbonate deposits that overlay it.

Neanderthals may have painted their caves, too

A vaccine could help smokers kick the habit by getting rid of the 'hit'. A team at Weill Cornell Medical College in the US has created a genetically-modified virus that contains instructions for making antibodies that stop nicotine from entering the brain.

A new fuel cell that can draw power from the fluid surrounding the human brain raises the prospect of self-powered implants to help paralysed patients move their legs. The device developed at MIT breaks down glucose, converting it into electricity.

Terms such as ampere, wavelength and vacuum have been translated into British Sign Language, removing a barrier to deaf people learning science.

GOOD NEWS

BAD NEWS

Levels of nitrogen dioxide inside a city flat with a gas cooker were three times higher than those outside, and well above recommended limits, University of Sheffield researchers found. The levels of particles small enough to enter the lungs were also higher than the UK target for outdoor air quality.

Video-gamers may think they are great multi-taskers but research suggests that they are no better at driving while talking than anyone else. Scientists at Duke University in the US found that students did less well in a driving game when they were being asked questions.

Men who drink more than seven cups of tea per day may be more likely to develop prostate cancer, according to a University of Glasgow study tracking men's health for 37 years.

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brennan
Gymnopedie
11:17am HDD 2/19 0:31 Random
Vol.
Back
Next
Eject
Play/Stop
Push - Menu
JB7
Jack Johnson
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- Delete tracks you don't like
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- One button plays the entire music collection at random
- Plays MP3 downloads - future proof
- Clock with alarm
- 60 Watt, 4.8 x 16 x 22 cm steel and aluminium construction
- Backup music to external USB hard disk for safe keeping
- You can use it with your existing hi-fi or on its own

Introducing the new and truly amazing Brennan JB7

What's the point in owning hundreds of CDs worth thousands of pounds if you never listen to them? The problem with CDs is that it's quicker to make a cup of coffee than dip into a CD. Try timing how long it takes to pick a CD, load it in the CD player, play a snippet from a track or two, eject it and put it back where it came from. Then there is the problem of finding music. The print on a CD spine is tiny. What if the track is on a compilation CD? What if the CD is in the car? Then there is the clutter.
You need to keep your CDs near the player or you won't play them. So you are forced to share your living space with literally hundreds of cheap plastic boxes.

CDs are a great way to listen to music but they are also inconvenient, inaccessible and a bit of a chore.

The Brennan JB7 is a CD player with a hard disk that stores up to 5,000 CDs* - and that's not all

It saves space and clutter and delivers near immediate access to an entire music collection. JB7 owners rediscover then fall in love with their music again simply because the Brennan makes it so accessible.

The Brennan also records from vinyl and cassette so you can enjoy your entire music collection but keep the originals in another room or retire them to the attic.

Over 30,000 sold. Lots of happy customers.

"Until you actually own a Brennan or at least see one operating, you can't really put into words how wonderful and amazing it is. You wonder how something so small, compact and stylish can do so much! Now, with the touch of a button on the Brennan, it randomly plays music and I no longer have to make such decisions by myself. It makes them for me." Mr G. Patterson, N. Ireland

The Brennan JB7 is available in Cobalt Blue or Titanium Metallic

MONEY BACK GUARANTEE

If you're not suitably impressed with your Brennan JB7 we'll collect it free of charge and refund you in full.

*See copyright message on the Brennan website

The face behind Brennan

Martin Brennan, who designed the JB7, has worked with Sir Clive Sinclair and Sir Alan Sugar and has designed over 20 silicon chips in his career. He was a real pioneer in the computer games industry - he played a central role in the design of the worlds first 64 bit games computer.

Ever since CDs were invented Martin wanted a CD player that would hold his entire CD collection. He wanted something as simple to use as a light switch but at the same time something that would let him find a particular track without leaving the armchair.

A word about copyright

"In 2006 the record companies said unequivocally that they are happy for you to load your own CDs onto a hard disk but the Advertising Standards Authority have asked us to tell you that it is unlawful to copy material without the permission of the copyright holder."

Martin Brennan

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brennan

The Analyst

Robert Matthews

When it comes to Earth's atmosphere, taking chances could be dangerous

Let's imagine you've come up with a cunning plan for saving the world from global warming – like, say, spraying stuff into the air to bounce some of the Sun's heat back into space. How would you find out if it works? If you are a scientist, the answer's obvious: carry out an experiment.

And that's exactly what the Stratospheric Particle Injection for Climate Engineering (SPICE) project team were going to do – until, earlier this summer, they decided not to. They had various reasons for giving up, but chief among them seems to have been fear of annoying whiny, hand-wringing environmentalists. The SPICE guys did point out that they were only going to tie a hosepipe to a balloon and let it spray a couple of bathtubs of water over a field from 1,000m up. But it made no difference: the test has been cancelled, and the team has been reduced to doing computer simulations.

Usually I don't have a lot of patience with those who start waving placards the moment they see a lab coat. But for once, I'm with the whiny hand-wringers. That's because when it comes to these ideas for saving the planet – known as 'geo-engineering' – I don't think science is up to the job.

Just suppose the SPICE guys had gone ahead. In all likelihood, there would have been no problem at all. So then what? Well, being scientists, the SPICE guys would doubtless have gone on to perform an experiment to see if spraying water from a high-altitude hosepipe really can act as a solar shield. And if that had worked, then they'd go on to an even bigger experiment to see what would happen on a really big scale – say, over an area the size of a city.

> "*Usually I don't have a lot of patience with those who start waving placards the moment they see a lab coat*"

SCIENCE ISN'T UP TO THE JOB
THE EARTH'S ATMOSPHERE IS TOO COMPLEX
H2O
SPICE

DANHILLIARD.CO.UK

At each stage, they'd be able to rely on the results of their previous experiments to guide the next step. Or could they? Just how confident can we be that small-scale experiments reflect what will happen when we 'go large'?

True believers in the scientific process may boldly go in the footsteps of the likes of Isaac Newton, who famously extrapolated the orbit of the planets from the fall of an apple. But like the story of the apple, such extrapolations can't always be trusted, especially when dealing with complex systems like the Earth's atmosphere.

Scientists have already had warning of this from their attempts to control the weather. They've long known that chemicals like silver iodide can trigger rain. Yet despite countless sums, simulations and experiments, they've never managed to do it reliably. It's becoming clear that there are so many variables involved that it may never be possible to guarantee the outcome.

Exactly 60 years ago this month, British scientists conducted classified rain-making experiments, with RAF aircraft dropping chemicals into clouds over Exmoor. Within hours, the village of Lynmouth suffered a flash flood that claimed dozens of lives and left hundreds homeless. A coincidence? Quite possibly – though documents unearthed years later suggest officials were sufficiently worried about a link that they ordered a cover-up anyway.

Scientists would doubtless dismiss it all as conspiracy theorist nonsense. But would they be willing to do the scientific thing, and re-run the Exmoor experiment to prove their claim? I doubt it, because if there's one thing we know for sure about the atmosphere, it's that it pushes science to its very limits.

The Futurist
Stephen Baxter

The future of Mission Control

The film *Star Trek: The Motion Picture* (1979) shows NASA's Voyager 6 returning to Earth after 300 years. It's met by the crew of the Enterprise, citizens of a world utterly transformed since Voyager's departure. And when Voyager tries to report its findings, no-one can read its signals.

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Voyager 6's problem was that its Mission Controllers were long dead. Our vision of a spacecraft's Mission Control comes from folk memories of Project Apollo, when a team of hard-working engineers would bust a gut for a couple of weeks as they sent their astronauts to the Moon. But in future, controllers will need to be able to handle missions of much longer durations.

Even today, the International Space Station has required continual ground support for many years, as have many unmanned missions. The Dawn mission to the asteroids has a minimum eight-year flight profile. The Cassini probe is still functioning eight years after arriving at Saturn. And NASA's real-life Voyagers, which toured the outer planets, are now travelling onwards into interstellar space, and still reporting back their findings some 35 years after they were launched.

Future missions could take even longer. An interstellar probe might take a century to reach Alpha Centauri, and then spend decades exploring. Imagine trying to support a century-old space probe, a relic of an era as remote as our age is from the Model T Ford! But there are precedents. The US Air Force's B-52 strategic bomber will mark 60 years in service in 2015, and the USAF intends to keep some variants of the aircraft flying until at least 2040, 85 years after it entered service. But B-52s can be upgraded on the ground, options that won't be available for a spacecraft.

NASA has already learned from the Voyager missions how to handle some of the problems of long duration, such as the obsolescence of the technology, and the original designers retiring and taking their hands-on wisdom with them. Modern software monitors clunky 1970s telemetry, watching for alerts to bring to the attention of a much-reduced human staff.

Culturally, old projects tend to lose support, but NASA has an outreach programme to keep Voyager in the public eye. In the longer term an 'academy' preserving a spacecraft's old technologies may be needed. Today's hobby enthusiasts in early steam engines, aircraft and electronics willingly preserve lost skills and technologies; their future analogues might contribute to the support of elderly spacecraft.

What about very long missions, such as a 1,000-year voyage to a remote star? History shows that in Europe over 1,000 years, the Catholic church has been the only enduring institution. In Europe's Dark Ages, monks worked to keep the learning of the past alive. The Mission Control of the future may be less like the white-shirted frenzy we saw in the movie *Apollo 13*, and more like the calm of a monastic scriptorium.

MEET THE COLUMNISTS

The Futurist
Stephen Baxter

A pre-eminent science-fiction writer and regular *Focus* contributor, his books include *The Science Of Avatar* and the popular *Destiny's Children* series.

The Insider
Henry Gee

A senior editor of the respected science journal *Nature*, Henry is the author of several books, including *The Science Of Middle Earth*.

The Eco-sceptic
Tom Heap

Tom is an expert on all things green. He presents *Panorama* on BBC One and *Costing The Earth* on Radio 4, which questions accepted truths on green issues.

The Analyst
Robert Matthews

After studying physics at Oxford University, Robert became a science writer. He is a visiting reader in science at Aston University.

The Medic
Michael Mosley

After training as a doctor, Michael joined the BBC to become a presenter, writer and producer. He's *The One Show*'s science man and presented *The Story Of Science*.

The Eco-sceptic
Tom Heap

We're to blame for the bat's bad name

Just as Batman battles for our sympathies in his new film *The Dark Knight Rises*, bats themselves are caught up in a struggle to prove themselves mankind's friend, not foe.

I should confess an interest. I love bats and have been lucky enough to handle them and even learn how to sex them (you blow on their furry chests and judge the prominence of their nipples). For many without this intimate experience, they are burdened with some dark cultural baggage thanks to the likes of Dracula, alongside some more serious concerns such as their ability to spread rabies.

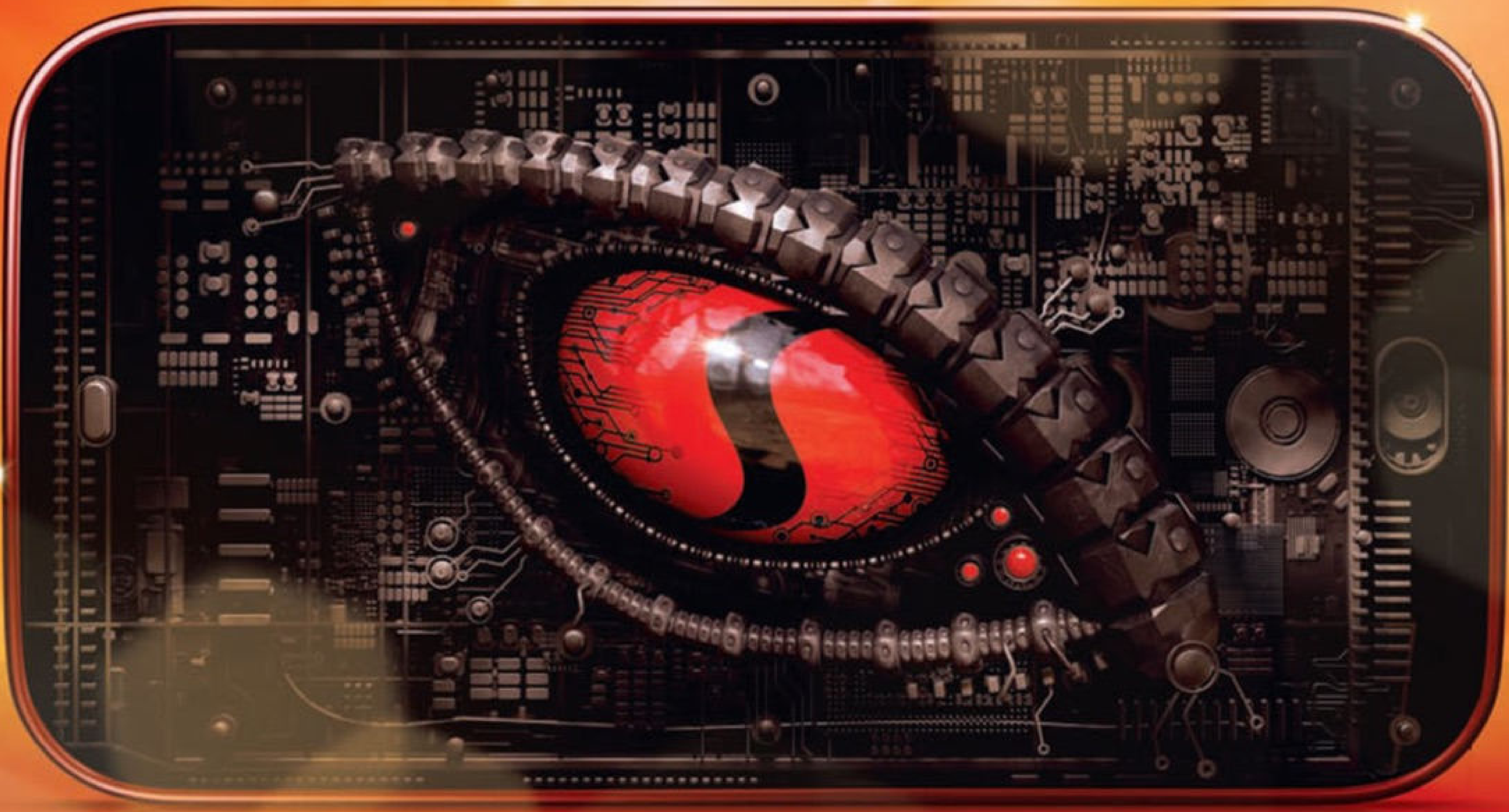
It's as disease vectors that they have recently been in the dock, blamed for spreading emerging diseases like SARS and even strains of influenza. They're the world's most numerous mammals and this, combined with their mobility on the wing, gives them huge scope to both pick up pathogens and pass them on. So from Australia, through Asia and on into Latin America, bat colonies are being deliberately eradicated or destroyed by development.

But new research suggests we hold more responsibility than the bats, since our attacks on their environments could be making them more infectious by undermining the 'dilution effect'. Mexican bat expert Rodrigo Medellin believes that in natural conditions, a potential pathogen is diluted by the range of biodiversity the bat contacts: birds, reptiles and other mammals. Some of these hosts will be dead ends, lightening the pathogen load and reducing the risk of contagion. But in a disturbed ecosystem just a few species become superabundant, creating the ideal conditions for high infectivity.

Medellin has just won a Whitley conservation award and grant to test his theory. If proved correct, this will show we have nothing to fear from bats, he says – so long as we preserve the forests where they live.

WHAT DO YOU THINK?

Are bats or humans to blame for the spread of emerging diseases?
post@sciencefocus.com



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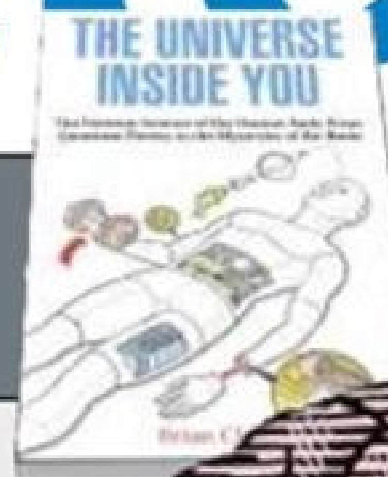
Your Letters

Write in and Win

Message of the month



The 'Message of the month' writer wins a copy of *The Universe Inside You* by Brian Clegg (Icon Books, £12.99)

Turing's legacy

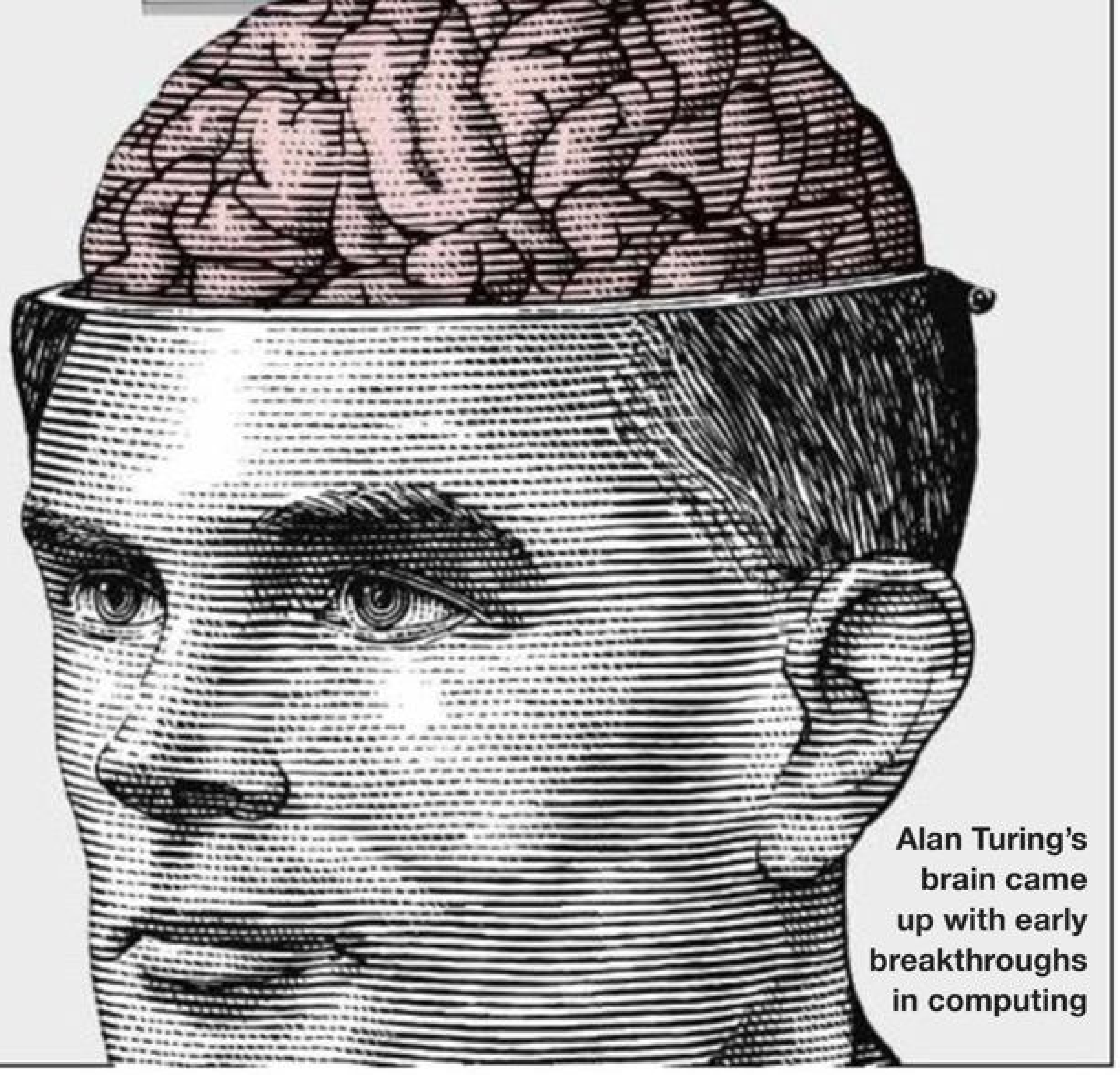
There were two very interesting articles in July's edition. The linked artificial intelligence/Alan Turing article was excellent. Don't get me started on Alan, a genius who should have been knighted as a war hero for saving thousands of lives by developing the first true computer, and who was persecuted into committing suicide.

Gordon Brown felt it necessary to give a public apology for how Mr Turing was treated by the British justice system. Although I realise you are a science magazine, I feel you needlessly skirted around his treatment and the causes of his death.

The other article that interested me was on multiple universes. If you subscribe to alternative universe theory, also discussed in this article, then perhaps somewhere else I'm not writing this and Alan Turing lived to celebrate his 100th birthday this year.

Simon Elson, Burton On Trent

Alan Turing's death at such a young age (41) was indeed tragic – who knows what else he would have gone on to achieve? As for multiple universes, I find it hard to get my head around them – they are truly mind-boggling. ***–Ed***



Alan Turing's brain came up with early breakthroughs in computing

Rise of the robots

I disagree with Mr Laurence Kingsbury ('Post', July issue), who suggests we should "make computers see the human race as God" to prevent them getting what they want via unethical means. This scenario would inevitably result in disaster. They would eventually discover that humans, unlike God, are fallible and then we'd be in real trouble.

I think it's much more effective (and realistic) to instead treat emerging artificial intelligence in the same manner as a child, and teach by setting 'ground rules' (like Asimov's famous three laws), giving it a good example to copy from its human builders. It will take some time and there will be mistakes along the way, but it works for us most of the time, so why not machines?

Robyn Woodbridge

Turing's head

I'm a frequent reader of the iPad issue of *Focus* magazine and on a couple of occasions, articles have had distracting animations, making them difficult to read. The most recent example I can think of is the Alan Turing article, which had 'pulsating' bubbles around the head picture. I can understand someone wanting to make the iPad issue look exciting but can they please be removed, or could you at least provide readers with a way of switching them off?

Alex Beech

Thanks Alex, we welcome feedback on both our iPad and print editions. We try to strike a balance between information and entertainment, but you make a good point about readability. ***–Ed***

Lit by the Moon

Alastair Gunn's explanation of 'Why is moonlight white?' (July, p71) puzzled me. His argument that moonlight is 'generally' insufficient to fire our colour receptors would seem to explain the observations, were it not for the fact that in total lunar eclipses, which are dimmer than the full Moon, we see the Moon as a quite distinct red. Am I missing something crucial?

Chris Gidzewicz

Alastair Gunn replies: *This is a valid point. However, I was referring to the dimness of 'moonlight' itself rather than the dimness of the face of the Moon. The Moon is bright enough to trigger colour-receptors in the eye. However, 'moonlight' reflected from objects around us appears white because, by comparison, it is very much fainter than light coming directly from the Moon.*

Alien visitors

Leaving aside whether we would recognise

STEVEN NOBLE, THOMAS PRINGLE, SUPERSTOCK, NASA

WHAT DO YOU THINK?

post@sciencefocus.com
Focus magazine,
Tower House, Fairfax Street,
Bristol, BS1 3BN

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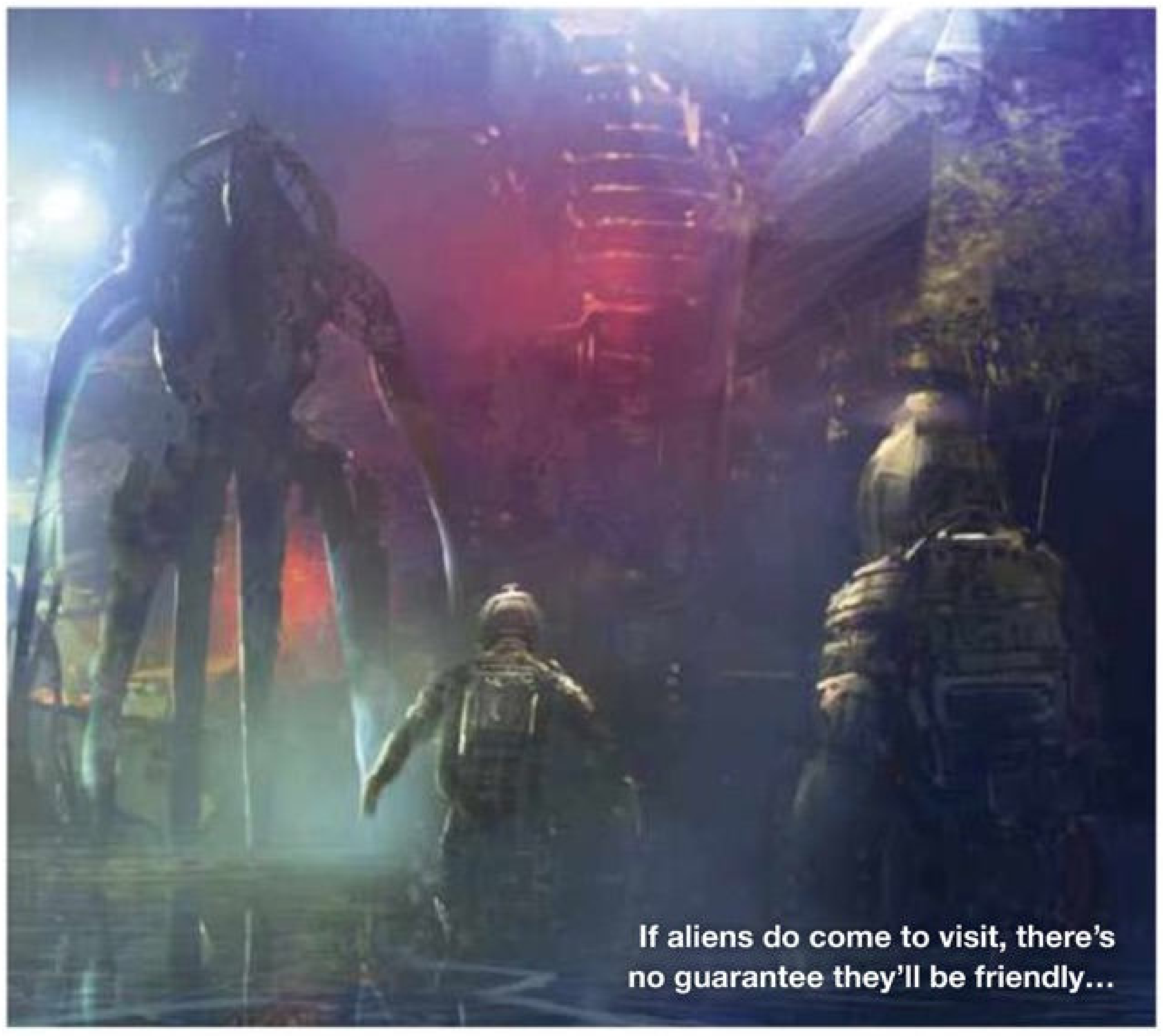
intelligent life if we saw it, a thought came to me when reading the final paragraph of 'Reach for the stars' (p52, June). Would intelligent beings really want to make contact with our species?
Hilary Foxwell, London

I guess it would depend whether they were friendly like ET, *or more like the creatures from the* Alien *films.* ***–Ed***


If aliens do come to visit, there's no guarantee they'll be friendly…

The *Focus* effect

I love science and inventing things and I am only nine. The first time I ever read your magazine was when I was at the dentist. I absolutely hate the dentist and couldn't stop worrying about what would happen to me – would I get my teeth pulled out? Then my mum pointed out that there was a *Focus* magazine on the rack. She started to read it to me and it made me stop worrying immediately.

I think you give out great facts every month, especially the Top 10s – they are really interesting. If I had to rate your magazine I would give it a 10 out of 10.
Matthew Manders

Glad we soothed your dental worries Matthew. Don't worry too much about dentists – they're scientifically trained too! ***–Ed***

I think you'll find…

I find your list of 'Top 10 heaviest land animals' (June, p76) rather misleading in that you include the walrus (*Odobenus rosmarus*) at number six. The walrus is a member of a group of semi-aquatic marine mammals known as pinipeds which also includes seals and sealions. These cannot really be classified as land animals as they spend the majority of their lives in the ocean, only visiting land for the activities of mating, breeding and moulting.

If you have decided to include pinipeds in the list, then you should have included other pinipeds like the southern elephant seal (*Mirounga leonina*), the bulls of which can weigh up to 4,000 kg. This mammal would be placed third in the list, beaten only by African and Asian elephants.
Derek Staff, Bicester

A walrus moulting (we presume)

In last month's 'Q&A' (Summer, p79), Tom Brooks asks: 'What would happen if you set off a firework on the Moon?' to which Alastair Gunn replies: 'Nothing. Since there is no oxygen in the Moon's atmosphere, there is nothing with which the inflammable materials in fireworks can ignite'. This is rubbish!

The 'inflammable material' in fireworks is gunpowder, which contains an oxidiser (usually potassium nitrate) which provides all the oxygen needed for combustion. The problem with using fireworks in a vacuum would be lighting them, as both matches and gas lighters need oxygen. But ignition could still be achieved by hot-wire igniters or other means.
Brian Rumary

Thank you for all your letters on this. It's true that fireworks carry their own supply of oxygen but experiments under vacuum conditions have shown that even if they can be lit, the key chemical reactions don't work. These are triggered by convective heating inside the firework, and that requires a substantial supply of air. ***–Ed***

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CONTRIBUTORS
Acute Graphics, Robert Banino, Stephen Baxter, Susan Blackmore, David Bodycombe, John Brophy, Dallas Campbell, Marcus Chown, Jerry Coyne, Heather Couper, Lewis Dartnell, Emma Davies, Russell Deeks, Jane Douglas, Flatliner, Alastair Gunn, Timandra Harkness, Tom Heap, Nigel Henbest, Dan Hilliard, Spencer Kelly, David Kennedy, James Lloyd, M Paul Lloyd, Bill McGuire, Tim Marks, Gareth Mitchell, Paul Monckton, Michael Mosley, Hazel Muir, Darren Naish, Kelly Oakes, Jheni Osman, Richard Palmer, Paul Price, Kate Ravilious, Steven Rose, Frank Ryan, Steve Sayers, Chris Sinclair, Paul Sutherland, Bill Thompson, Magic Torch, Luis Villazon, Paul Weston, Ruth Williams, Paul Wootton, Jonathan Wright

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INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
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Questions at the frontiers of... EVOLUTION

Evolutionary biology is a largely historical science that involves reconstructing the past. **Jerry Coyne** outlines some of today's key issues

Q Was the course of evolution inevitable?

In his 1989 book *Wonderful Life*, palaeontologist Stephen Jay Gould suggested that if we rewound the tape of life to Earth's beginning and watched it again, we'd see a different programme. Had the contingencies of evolution – such as asteroid strikes and random mutations – varied slightly, we would now have an entirely different set of plants and animals. Other scientists (religious ones) disagree, claiming that at least one evolutionary outcome was inevitable: *Homo sapiens*, a divinely preordained species capable of apprehending and worshipping a deity.

The answer to the question of inevitability is an unsatisfying 'don't know'. If we were to vary the starting conditions of life slightly so that the first living thing appeared in a different place, or the climate wasn't quite the same, or an asteroid didn't strike our planet 65 million years ago, would evolution produce the same end products that we're familiar with? In other words, how robust is the evolutionary process to differences in starting conditions and to variability in events through time?

On one hand, it seems that the trajectory of the history of life has been highly dependent on chance. Mammals evolved at about the same time as dinosaurs (roughly 210 million years ago), for instance, then spent the first 150 million years of their existence scurrying around beneath their mighty reptilian overlords. It took the serendipitous extinction of the dinosaurs courtesy of an asteroid strike to light the fuse of mammalian diversity.

But on the other hand, we *do* see deterministic processes in the history of life – processes that yield similar outcomes from dissimilar starting points. For example, we see hydrodynamic streamlining not only in fish, but also in marine mammals (porpoises) and ancient reptiles (ichthyosaurs). This is the process we call 'convergent evolution'.

So the bottom line is that both chance and determinism play roles in evolution. The argument then becomes one of degree: does one factor trump the other? Here, regrettably, we can do little beyond throwing up our hands.

Q Why do organisms have sex?

It's possible to reproduce without sex: many species do it, including microorganisms, lizards, fish and plants. In fact, it turns out that asexual reproduction (without sex) has a big evolutionary advantage.

Imagine that each human couple can leave two offspring, on average one male and one female. If a female had a mutation that allowed her to reproduce asexually, she'd have a tremendous evolutionary advantage. In the next generation, such asexual females would produce two females instead of one, meaning that these females would effectively have double the reproductive rate of their sexual neighbours. The sexual females (and their male offspring) would therefore eventually be crowded out by the asexual females.

This disadvantage of sexuality – the production of half the amount of offspring – is often called the 'two-fold cost of sex', but it's really the cost of producing males who can't bear children. Despite this cost, the vast majority of species on Earth reproduce through sex. Why? There must be some evolutionary advantage of sex that offsets the cost of producing useless males. Evolutionary biologists have offered many different suggestions, but it's still not clear that any of these provides a sufficient advantage to overcome that two-fold cost.

One promising explanation involves parasites and pathogens. Every plant and animal is afflicted with these burdens, and natural selection favours the evolution of resistance. Yet pathogens in turn evolve to defeat their host's defences, yielding a never-ending evolutionary 'arms race'. Asexual hosts can't respond quickly because their offspring are genetically identical to the parents, lacking the genetic variation that fuels evolutionary change. Sexuality offers a leg up, because

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you can produce genetically variable offspring by mixing and shuffling your genes with someone else's.

Is the evolutionary pressure from pathogens a general explanation for the existence of sex? Once again we're stymied by evolution's historical nature. Even if the presence of parasites can account for sex in existing species, it doesn't necessarily follow that this was the reason why sex first originated. Sex is, in fact, a surprisingly tricky problem.

Q How much of human behaviour reflects our evolutionary past?

What does it mean to be human? Part of the answer involves knowing which of our behaviours were instilled in our ancestors by natural selection. This is the purview of the field of 'evolutionary psychology'. Unfortunately, its popularity – as measured in books and articles that give Darwinian explanations for everything from homosexuality to music – isn't a sign of scientific rigour when viewed close up.

It turns out to be hugely difficult to determine what portion of our modern behaviour was beneficial in our ancestors. For one thing, our culture is far more elaborate than that of any other animal, being transmitted instantly from individual to individual through emulation. Is a male preference for young, blonde, curvy women a function of past evolution in favour of choosing mates with clear reproductive potential? Or is it simply a function of what we see on the covers of magazines?

"Sex is a surprisingly tricky problem"

These debates are important. To what extent are gender differences in academic performance in different subjects, for example, due to genetic evolution versus cultural differences? It's hard to tell because it's unethical (not to mention impossible) to settle the issue by raising boys and girls in completely gender-neutral environments. And since many of our behaviours evolved thousands or millions of years ago, under unknown conditions, we're often forced into speculative historical reconstructions, cynically known as 'just-so stories'.

Some of our behaviour is clearly due to natural selection. We favour our kin over non-kin, an evolutionary prediction met in many animals. Eating, sleeping, and copulating all promote our survival and reproduction. The greater choosiness of females than males in finding mates, predicted by evolutionary theory and seen in most animals, is also borne out by psychological tests. And our penchant for sweets and fats, now a maladaptive taste that leads to obesity and heart disease, was probably a valuable asset to our hungry ancestors on the savannah.

But when you read evolutionary explanations about why gentlemen prefer blondes, or why so much of the world is religious, you should always ask yourself two questions. First, could these traits be culturally influenced and not genetic? More important, what is the evidence for whether these behaviours were favoured in our ancestors by natural selection? My own standard for judging whether our behaviours represent evolutionary adaptations is this: employ the same rigorous scrutiny used by biologists when deciding whether studies of behaviour in non-human species should be published in scientific journals. By those lights, much of 'pop' evolutionary psychology doesn't pass muster. ■

Prof Jerry Coyne is an evolutionary biologist at the University of Chicago. His most recent book is* Why Evolution Is True *(OUP, 2009)

For more on the limits of human performance, listen to *Beyond Bolt: The Human Limits* on BBC iPlayer.

ILLUSTRATION BY PAUL PRICE

BEYOND USAIN BOLT

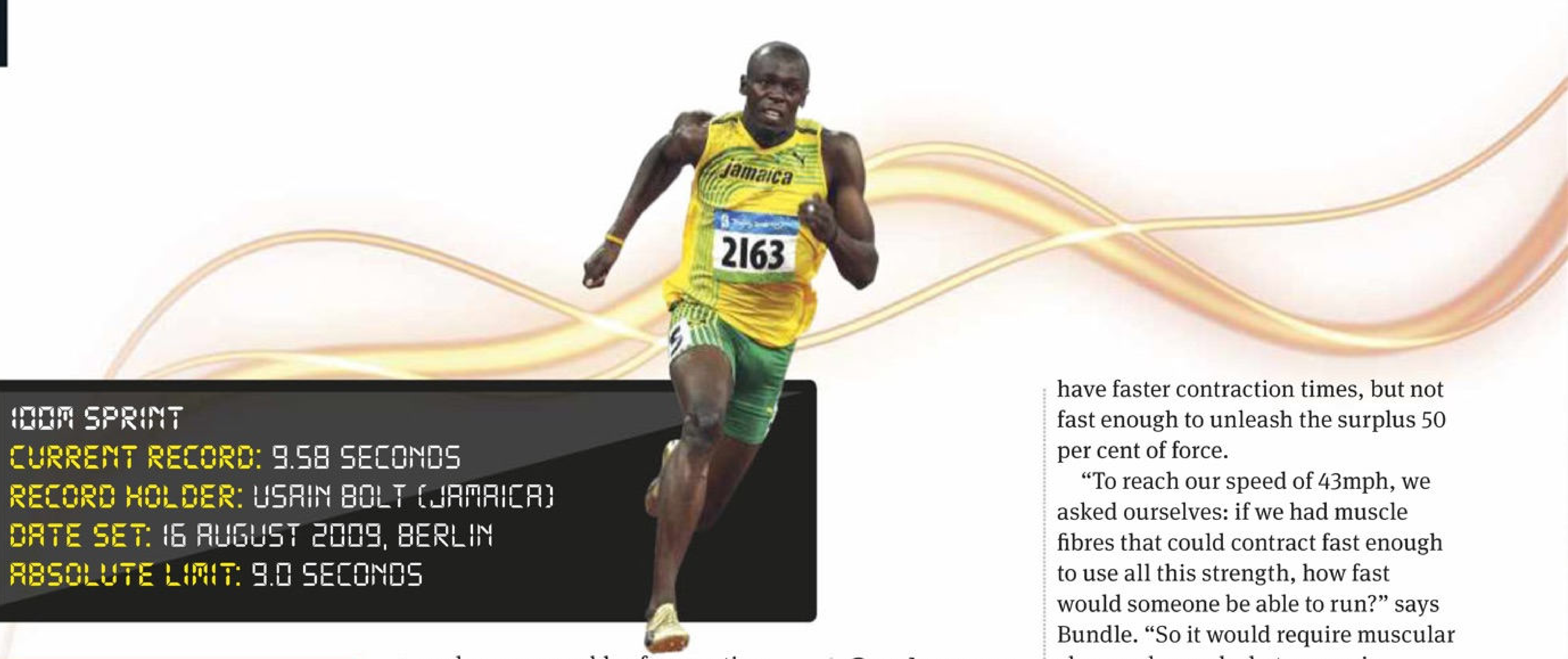
Just what is the human machine capable of? **Kate Ravilious** investigates how far sporting world records can be pushed

Just four years ago in Beijing, Usain Bolt did something rather special. The Jamaican sprinter ran the 100m men's final in a time of 9.69 seconds, a new world record, crossing the finish line metres ahead of the field. What made his feat all the more impressive was that Bolt visibly slowed down before the race is over to celebrate, and still won by a comfortable margin. What's more, one of his shoelaces was untied.

Such a staggering achievement prompted pundits and scientists to enquire just how much faster Bolt might be able to run. A year later, in the final of the World Athletics Championship in Berlin, he provided an answer – 9.58 seconds. Shaving over a tenth of a second off the previous world record, it was the largest ever improvement in the 100m world record since the introduction of electronic timing.

With such leaps in the records still possible, it begs the question – how far can the human body be pushed? What would be the ultimate world records that simply could not be surpassed? Clearly no-one will be capable of running the 100 metres in four seconds or throwing a javelin 1,000 metres, but what is the limit?

With some world records likely to tumble this month, *Focus* consulted some of the finest minds in sports science to discover the limits of the human machine in five classic events. Read on to discover their conclusions – they may just surprise you. ►



100M SPRINT
CURRENT RECORD: 9.58 SECONDS
RECORD HOLDER: USAIN BOLT (JAMAICA)
DATE SET: 16 AUGUST 2009, BERLIN
ABSOLUTE LIMIT: 9.0 SECONDS

100M SPRINT

In the 100m sprint, despite Bolt's apparently superhuman efforts, it seems there's still a lot of room for improvement. While Bolt recorded a top speed of nearly 28mph in the 2009 world championship final, a team of biomechanics experts in the US say the human body is actually capable of 43mph. With this as a top speed in a 100m event, an athlete would cross the finish line in roughly seven seconds.

These jaw-dropping findings came from a series of experiments in which volunteers were placed on a sophisticated treadmill and told to sprint, run backwards and hop on one leg at full speed. One of the results was particularly interesting. "In one-legged hopping, the forces generated were 50 per cent greater than when the volunteers were running at top speed," says Dr Matt Bundle, director of the Biomechanics Laboratory at the University of Montana. In other words, our legs are capable of generating much more force than we are able to use when we sprint, so something else must limit the maximum speed.

Tests carried out in the early 2000s by biomechanics expert Dr Peter Weyand, then at Harvard University, point to one of the limitations. They showed that the leg swing time – the time it spends in the air moving forwards – is the same for everyone. "Whether you're an Olympian or a slow runner, the swing time is 0.34 seconds," says Bundle. So no amount of training will speed it up.

The treadmill tests provided another insight. When the volunteers ran backwards, their feet were in contact with the ground for exactly the same amount of time as when they ran forwards. "It suggests the muscle fibres in your leg have a maximum speed of contraction. This means there is a minimum time the leg needs to be in contact with the ground to generate enough force to keep you upright," says Bundle. Faster runners have faster contraction times, but not fast enough to unleash the surplus 50 per cent of force.

Our legs are capable of generating much more force than we are able to use when we sprint

"To reach our speed of 43mph, we asked ourselves: if we had muscle fibres that could contract fast enough to use all this strength, how fast would someone be able to run?" says Bundle. "So it would require muscular changes beyond what we see in humans today. We're unlikely to see these changes occur naturally (see 'Pushing the limits further,' p40). But we will continue to see individuals getting faster, although at some point that will stop."

How close to that limit we will get naturally is far from clear, as many factors come into play. Even psychology is involved. "Once one person breaks a psychological barrier, like running 100m in less than 10 seconds, then everyone else goes, 'Wow, we can do it too'," says Chris Hughes, a senior lecturer in biomechanics at the University of Worcester. No-one was even close to breaking the four-minute mile until Roger Bannister did it in May 1954. Yet within two months of Bannister's record, Australia's John Landy also broke it, soon followed by others.

Arguably the most significant factor determining athletic performance is genetics. Scientists have pinpointed numerous genes associated with running ability. For instance the R form, or variant, of the ACTN3 gene is found in male and female elite athletes more commonly than in the rest of the population. Genetic testing offers the prospect of being able to spot more individuals with the right set of genes. Atlas Sports Genetics in Colorado already markets an ACTN3 gene test to parents and coaches.

Evidently Bolt has many of the 'right' genes. "He is freakishly talented, and the only athletes able to beat him will be freakishly talented too," says Andrew Renfree, a senior lecturer in sports science at the University of Worcester.

So what will be the ultimate 100m sprint time achieved by natural ▶

PLAYING THE NUMBERS GAME

Can statistics reveal the body's ultimate limits?

Rather than studying the biomechanics of running to predict the ultimate 100m record, others have used mathematical models.

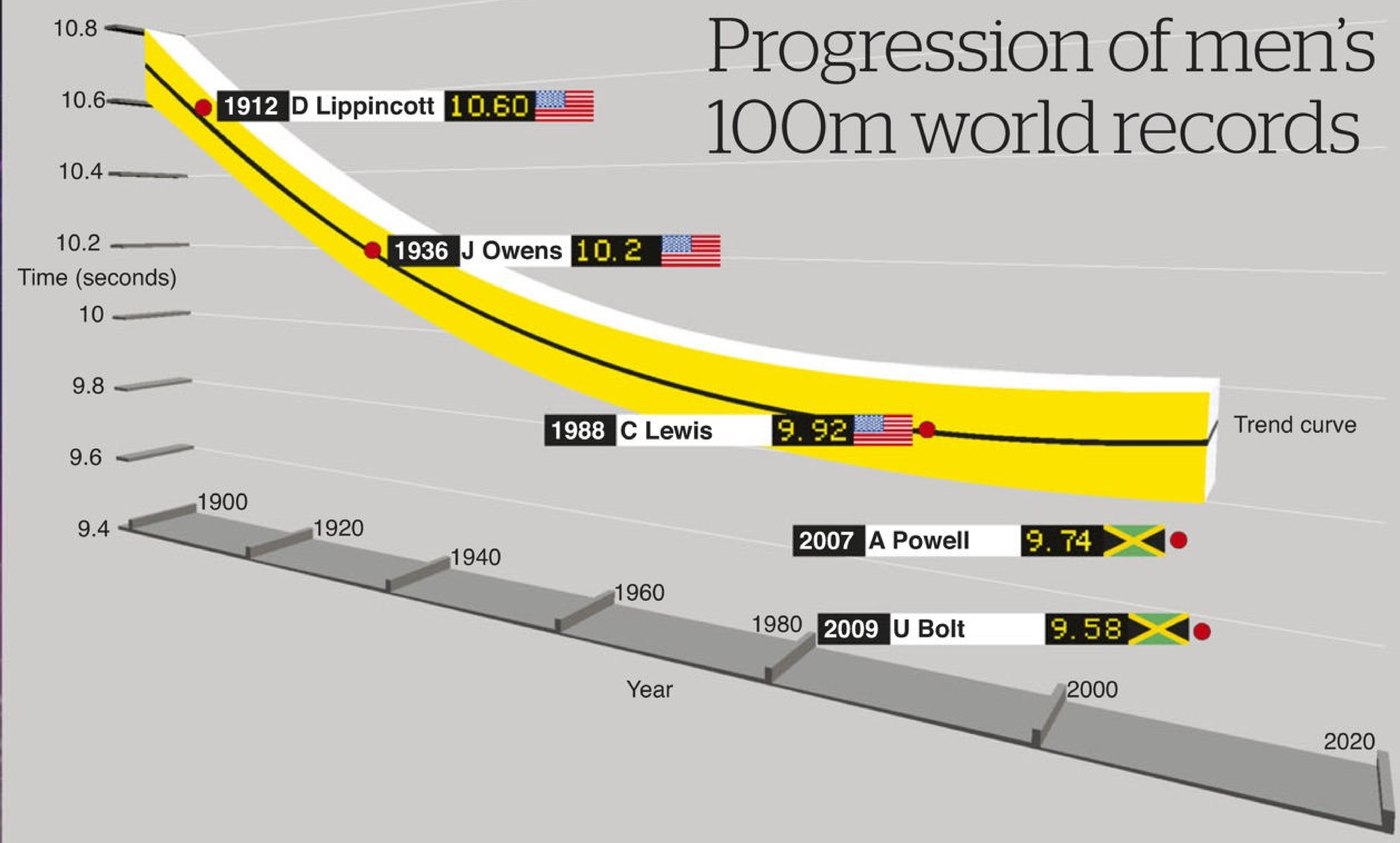
Physicist Jonas Mureika at Loyola Marymount University in Los Angeles, who spends much of his time studying cosmology and high-energy physics, successfully predicted a time like Bolt's would be achieved by 2009. But even he was dubious about his figures. "These fast times were coming too soon in the future, so I just ignored them." His model borrows techniques from seismology, to predict the occurrence of specific 100m times in the future from previous times.

Mureika has never predicted the ultimate record using maths, but others have. "People have predicted 9.3, 9.4 or 9.5 seconds," he says. "It all depends on the assumptions you build into the models: how you look at the historical figures and project into the future."

Mureika applied the maths of seismology to sporting statistics

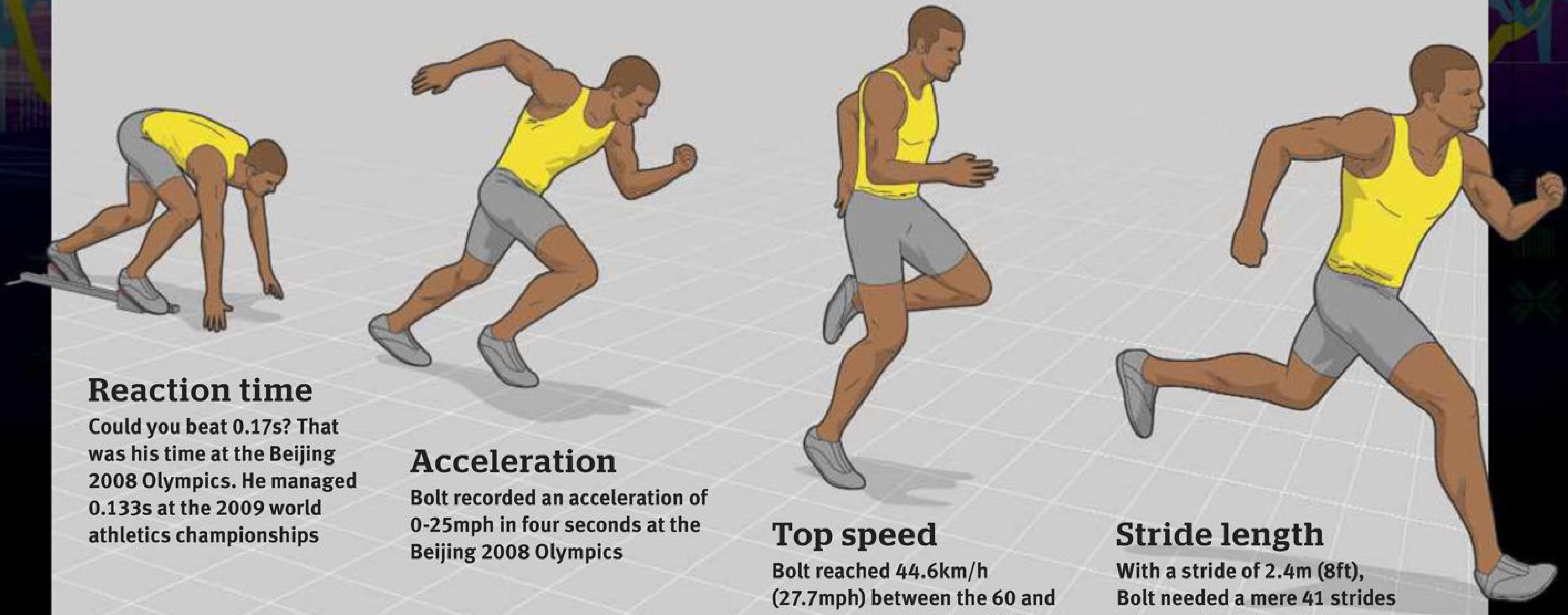
GETTY, JON ROU/LOYOLA MARYMOUNT UNIVERSITY, ILLUSTRATION BY ACUTE GRAPHICS

Progression of men's 100m world records



How to run like Bolt

The statistics that make him history's fastest man



Reaction time

Could you beat 0.17s? That was his time at the Beijing 2008 Olympics. He managed 0.133s at the 2009 world athletics championships

Acceleration

Bolt recorded an acceleration of 0-25mph in four seconds at the Beijing 2008 Olympics

Top speed

Bolt reached 44.6km/h (27.7mph) between the 60 and 80 metre marks in the 2009 world athletics championships

Stride length

With a stride of 2.4m (8ft), Bolt needed a mere 41 strides to cover the 100m at the Beijing 2008 Olympics

50M FREESTYLE SWIMMING
CURRENT RECORD: 20.91 SECONDS
RECORD HOLDER: CESAR CIELO (BRAZIL)
DATE SET: 18 DECEMBER 2009, SAO PAULO, BRAZIL
ABSOLUTE LIMIT: 18.15 SECONDS

▶ means? “If I had to make a prediction, I’d go with nine seconds being the absolute minimum time, and I think we’ll see it happen in the next 60 or 70 years,” says Hughes.

50M FREESTYLE

There is still plenty to play for in the 100m, but what about when it comes to sprinting through water? The 50m freestyle is the aquatic equivalent of the 100m track sprint, but slicing through water at speed requires completely different attributes.

Since water is much more resistant than air, swimmers have to use four times as much energy as runners to cover the same distance. Physically, the ultimate 50m swimmer will have a preponderance of fast-twitch muscles – muscles that contract quickly – in their upper body, very long arms, short legs and gigantic feet which act like flippers. Michael Phelps, the US swimmer and six times Olympic medallist, is a near perfect example. His size 14 feet, dinner plate-sized hands, long torso, short legs and ‘wingspan’ of 208cm (12cm more than his height) all help to maximise his propulsion through the water.

High-tech full-body swimsuits, introduced in 2008 and banned by 2010, shattered records by squeezing swimmers’ bodies into an ultra streamlined shape and giving them extra buoyancy. Those bodysuit-aided records still stand, but scientists think it is possible to improve on them. Dr Benjamin Domb, orthopaedic surgeon and expert in sports physiology at Hinsdale Orthopedics in Illinois, has tried to calculate the fastest a human can swim, assuming that person has perfect swimming technique.

Swimmers have to use four times as much energy as runners to cover the same distance

He adapted the equation used to determine the terminal velocity of a skydiver – the speed they will be travelling when the force of the air pushing the skydiver back is the same as the force of gravity. In the case of a swimmer, this technique can be used to calculate the speed at which they’re travelling when they are generating their maximum propulsive force.

Using this equation, Dr Domb calculated that the fastest anyone could ever swim is 3.8 metres per second. When that person comes along, they will be able to cover the 50m in 18.15 seconds.

Dr Matt Bundle in the Biomechanics Lab at the University of Montana

MARATHON

At the opposite extreme to the sprints is the marathon. Here, the need for fast-twitch muscles is gone.

“The main factors that determine how fast you can run a marathon are the development of your aerobic system, and how much energy you need to run 1km,” says Bundle.

In other words, how efficient your body is at bringing in the raw material for energy production, oxygen, and how efficiently that energy is utilised. “As your aerobic system develops, you get a heart which can eject a greater volume of blood, more energy-producing mitochondria in your cells and more blood vessels within the muscles. This all helps move oxygen into your muscles,” Bundle adds.

But there’s a limit to the extent to which your aerobic system can develop – how large your heart can grow and how far your muscles can fill with blood vessels – and this will provide a limit on how far marathon times can come down.

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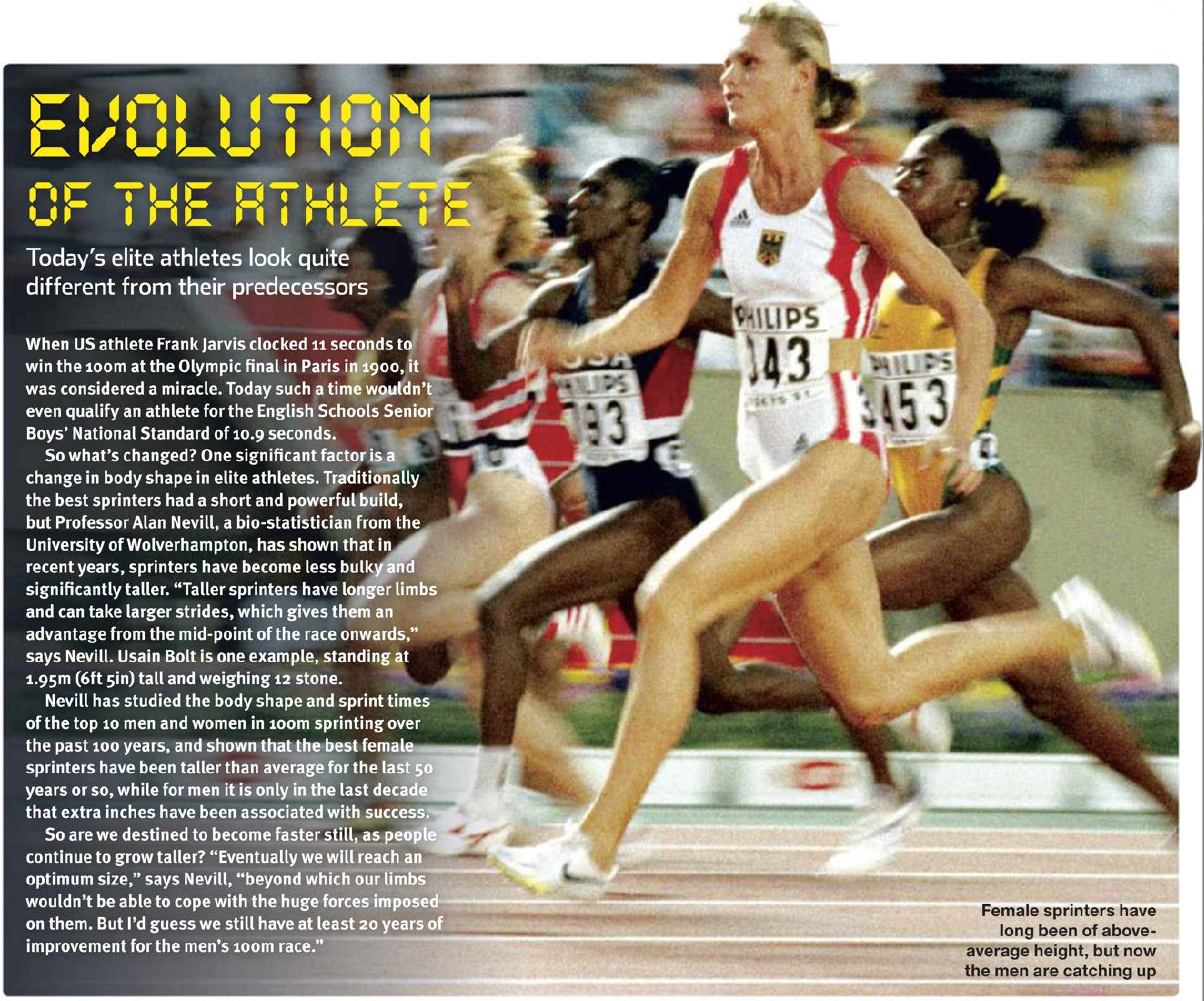


EVOLUTION OF THE ATHLETE

Today's elite athletes look quite different from their predecessors

When US athlete Frank Jarvis clocked 11 seconds to win the 100m at the Olympic final in Paris in 1900, it was considered a miracle. Today such a time wouldn't even qualify an athlete for the English Schools Senior Boys' National Standard of 10.9 seconds.

So what's changed? One significant factor is a change in body shape in elite athletes. Traditionally the best sprinters had a short and powerful build, but Professor Alan Nevill, a bio-statistician from the University of Wolverhampton, has shown that in recent years, sprinters have become less bulky and significantly taller. "Taller sprinters have longer limbs and can take larger strides, which gives them an advantage from the mid-point of the race onwards," says Nevill. Usain Bolt is one example, standing at 1.95m (6ft 5in) tall and weighing 12 stone.

Nevill has studied the body shape and sprint times of the top 10 men and women in 100m sprinting over the past 100 years, and shown that the best female sprinters have been taller than average for the last 50 years or so, while for men it is only in the last decade that extra inches have been associated with success.

So are we destined to become faster still, as people continue to grow taller? "Eventually we will reach an optimum size," says Nevill, "beyond which our limbs wouldn't be able to cope with the huge forces imposed on them. But I'd guess we still have at least 20 years of improvement for the men's 100m race."

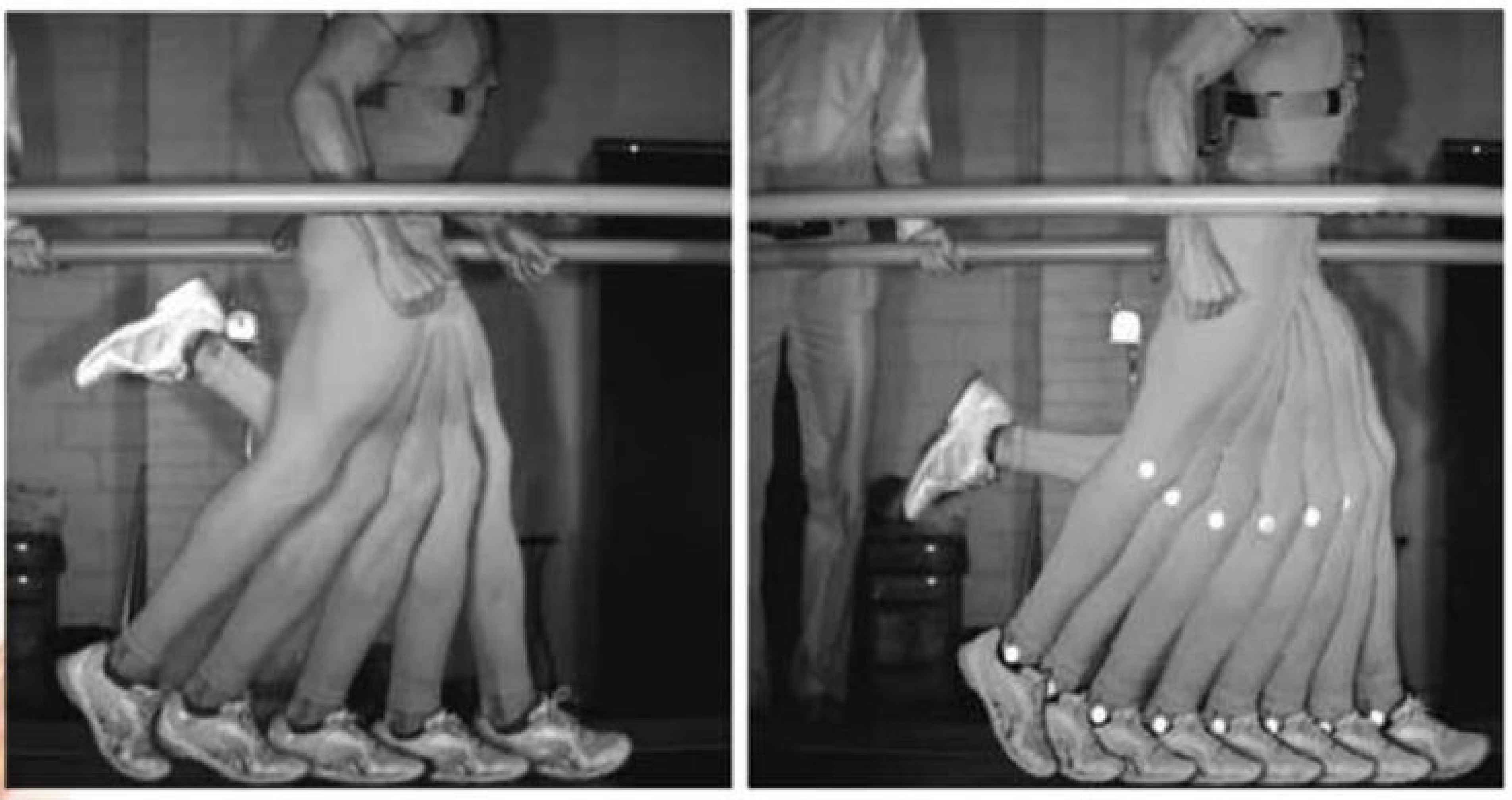
Female sprinters have long been of above-average height, but now the men are catching up

"The data suggests that male runners are pretty much at their maximum for the marathon," says Professor Alan Nevill, a bio-statistician from the University of Wolverhampton who has calculated the upper limits for endurance running records. However, Renfree thinks that mind power may still squeeze something out of the marathon record. "I think we'll see the two-hour barrier broken in the not too distant future," he says.

JAVELIN

Raw power becomes important again when it comes to the javelin. By running and then planting their foot hard, athletes transfer as much of their own energy as possible into the spear to make it fly. "The energy is shunted down the system – it's a bit like cracking a whip," says Hughes. ▶

A hopping foot stays in contact with the ground longer, exerting more force



MARATHON
CURRENT RECORD: 2:03:38
RECORD HOLDER: PATRICK MAKAU (KENYA)
DATE SET: 25 SEPTEMBER 2011, BERLIN
ABSOLUTE LIMIT: 1:59:38

JAVELIN

CURRENT RECORD: 98.48M

RECORD HOLDER: JAN ZELEZNY (CZECH REP)

DATE SET: 26 MAY 1996, JENA, GERMANY

ABSOLUTE LIMIT: 98.48M

> *Most sports scientists think the ultimate javelin thrower already exists*

▶ Since the redesign of the javelin in 1986 the record has crept up only slowly, suggesting that the javelin throwing technique has neared perfection point. Large arm muscles full of fast-twitch fibres are essential, but in terms of physiology and technique, most sports scientists think the ultimate javelin thrower already exists – Jan Železný, the Czech who set the record in 1996.

"In the case of the javelin, performance is mostly limited by the rules imposed on the sport. Until those rules change, it is difficult to progress further," says Hughes.

LONG JUMP

In contrast, the long jump is almost technology-free. When an elite long-jumper hits the take-off board, they produce a force equal to 12 times their own body weight. Large leg muscles are essential to cope with the strain of this force, but if they get too large they'll hinder sprinting ability.

"The ultimate long jumper has to find the sweet spot where they can hit the board as hard as possible, but still have strong enough legs to avoid their muscles collapsing," says Associate Professor Peter Weyand, a biomechanics expert at the Southern Methodist University in Dallas.

In the 1970s, Dr Gideon Ariel in the USA – one of the fathers of biomechanics – analysed Bob Beamon's staggering 1968 jump of 8.9m, a record that held for 23 years. He studied film footage and used a computer to calculate force, direction of force, acceleration and velocity of different parts of the body. His work showed that Beamon produced 1,700 pounds of force in his hip joint.

At this level, the average muscle attachments to the hip will simply tear, so it's unlikely anyone will produce significant advances on the current record. Ariel's prediction of an 8.96m ultimate long jump, made four decades ago, has yet to be achieved.

For all this study, there is still much we don't understand about the way an elite athlete's body works. When we solve some of the mysteries of the human body, it may lead us to reassess how far it can be pushed.

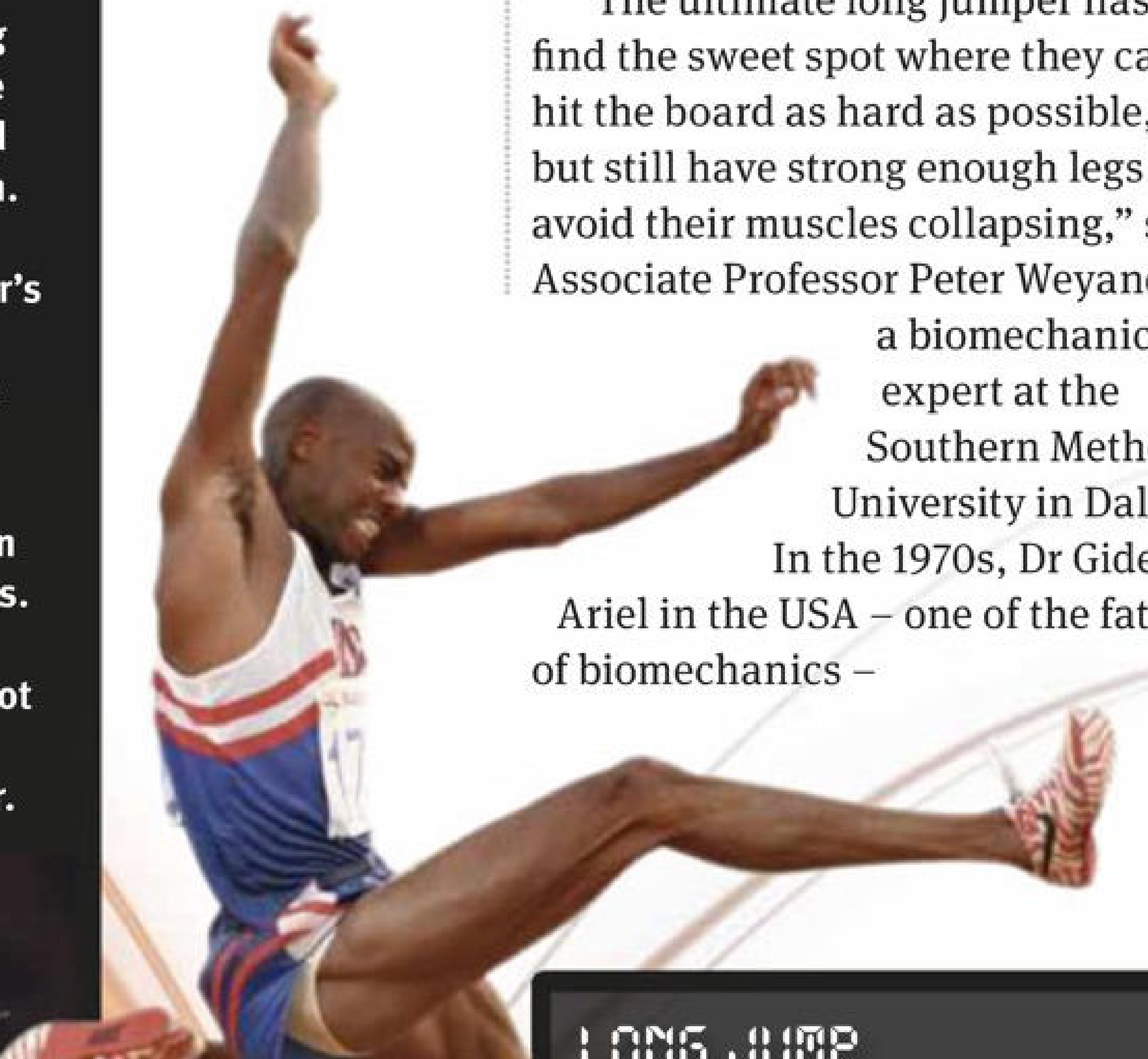
"We just don't know how Usain Bolt manages to produce 900lbs of peak force with every stride, when his foot is only on the ground for 0.03 of a second," says Weyand. "Fast-twitch muscle fibres alone are not enough to explain this tremendous force."

Whatever the body's ultimate limits are, it looks like we can expect records to fall this summer – and at many championships to come. ■

Dr Kate Ravilious is a science writer based in York

BBC RADIO 4 92–95FM & 198LW

On 18 July, Radio 4 broadcast *Beyond Bolt: The Human Limits*, presented by triple jump holder Jonathan Edwards. You can catch up on iPlayer at: www.bbc.co.uk/iplayer/radio



LONG JUMP

CURRENT RECORD: 8.95M

RECORD HOLDER: MIKE POWELL (US)

DATE SET: 30 AUGUST 1991, TOKYO

ABSOLUTE LIMIT: 8.96M

PUSHING THE LIMITS FURTHER

What effect could performance-enhancing technology have on ultimate records?

Ben Johnson's 100m in 9.79 seconds at the Seoul 1988 Olympics showed the effect drugs can have on performance. But another technique could prove even more potent. In 'gene doping', genetic material could be added to an athlete's DNA, or their existing genetic material altered – perhaps through injection into a muscle – to make muscles stronger or to increase the blood's oxygen-carrying capacity. "If you are looking for an area where you really could alter performance in fundamental ways, it would be gene doping," says Dr Matt Bundle, of the Biomechanics Laboratory at the University of Montana.

Such genetic changes could increase the rate at which leg muscles contract. "Fish vocalisation muscles and rattlesnake tail shakers have shortening velocities much faster than those of human leg extensors," says Bundle. "So we already have examples of genetic systems that generate the necessary structures."

But even with faster contracting leg muscles, the sprinter would be unable to top the 43mph predicted as achievable in Bundle's research. The force couldn't be applied fast enough in the short time the runner's foot would be on the ground. "Muscles don't provide their force instantaneously, there are a few steps in-between nervous system command and full force application that require time," Bundle explains.

Swing time – how long the leg spends in the air per stride – cannot be reduced, either. The human machine can only be pushed so far.

Testing urine samples for evidence of performance-enhancing drugs

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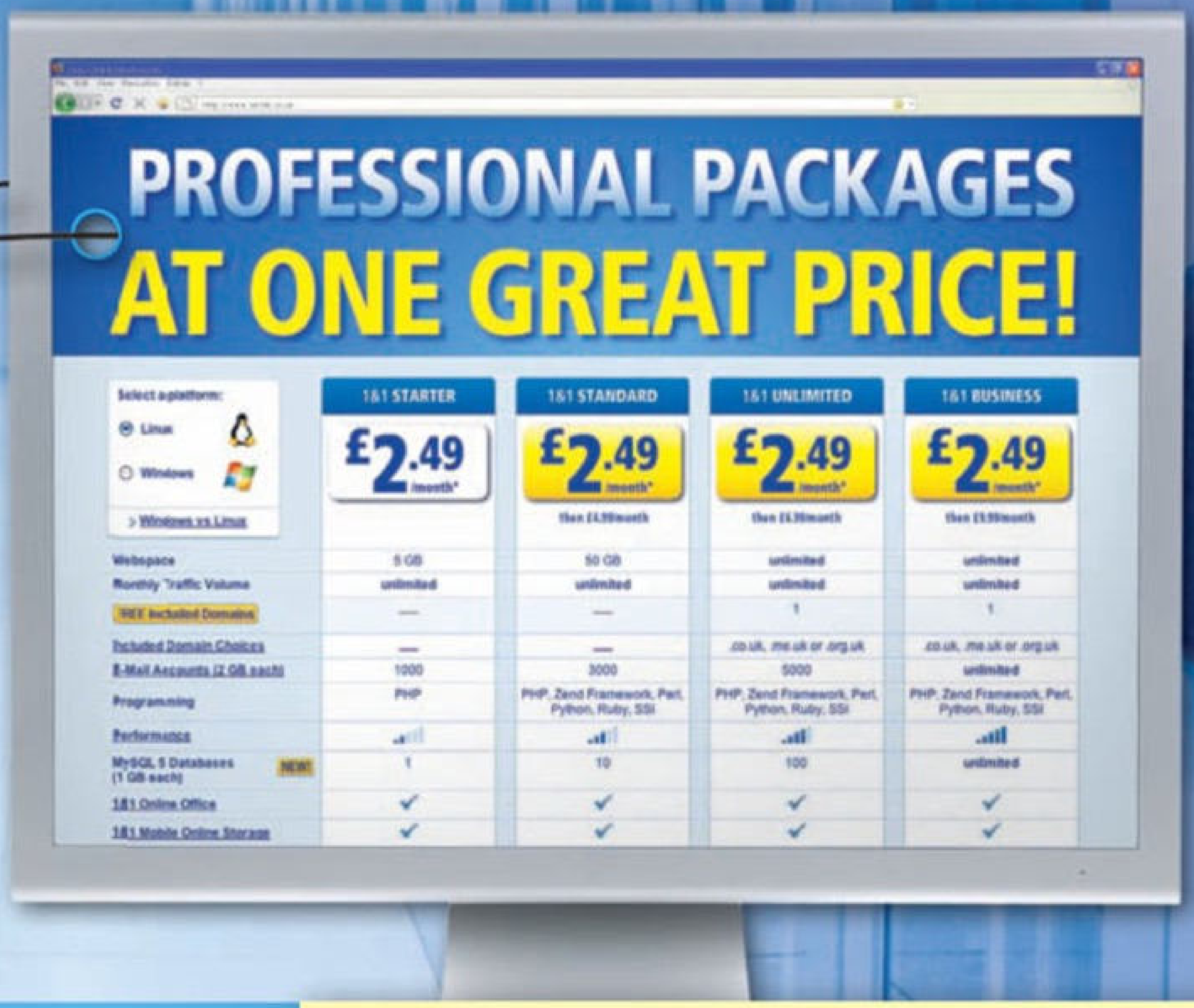

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FREE Included Domains	—	—	1	1
Included Domain Choices	—	—	.co.uk, .me.uk or .org.uk	.co.uk, .me.uk or .org.uk
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DIGGING FOR DARK MATTER

As scientists prepare to switch on a huge experiment buried deep underground, **Hazel Muir** investigates why it may just solve one of science's greatest mysteries

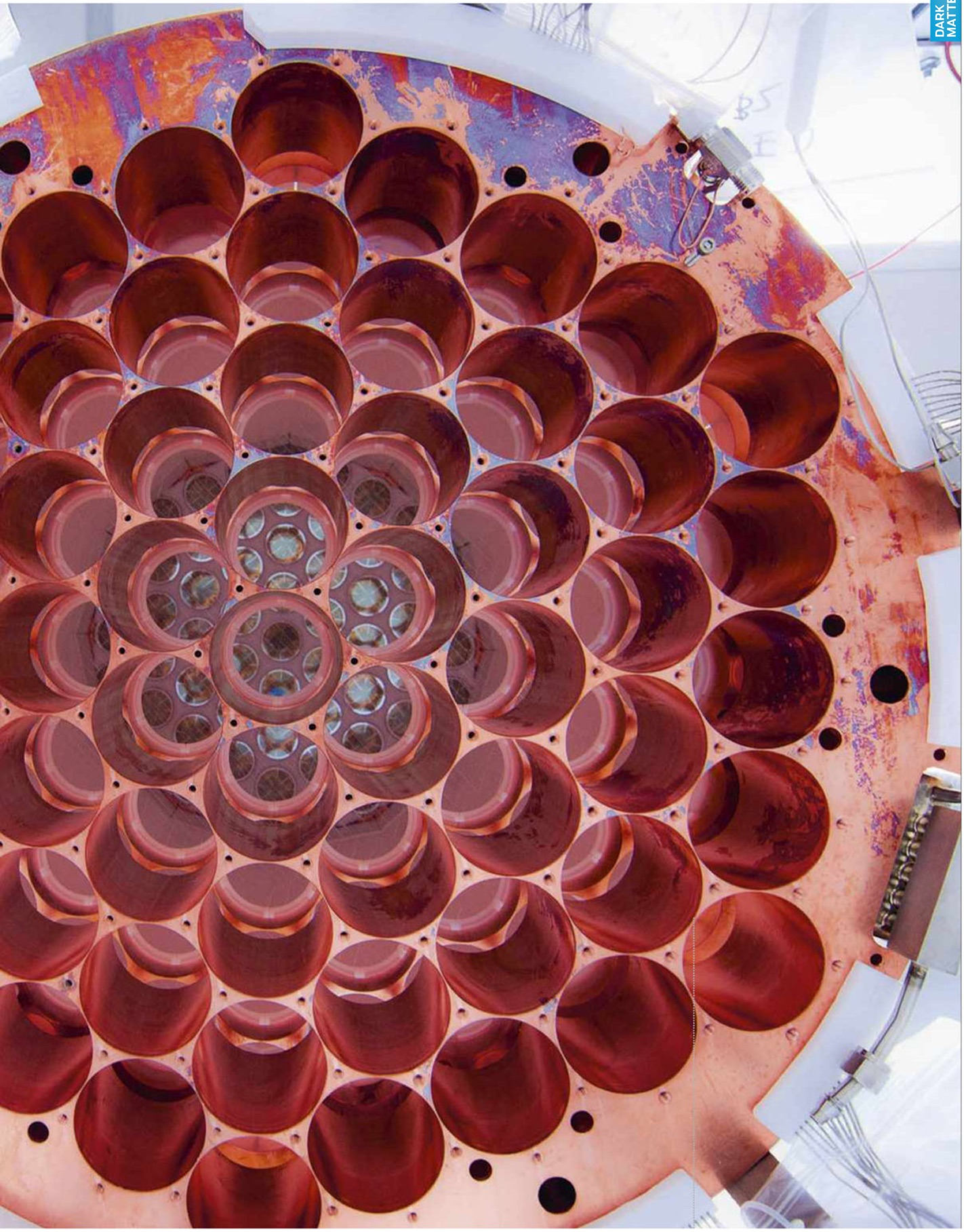
The LUX experiment is the most advanced device yet to be deployed in the search for dark matter

BROWN PARTICLE ASTROPHYSICS GROUP

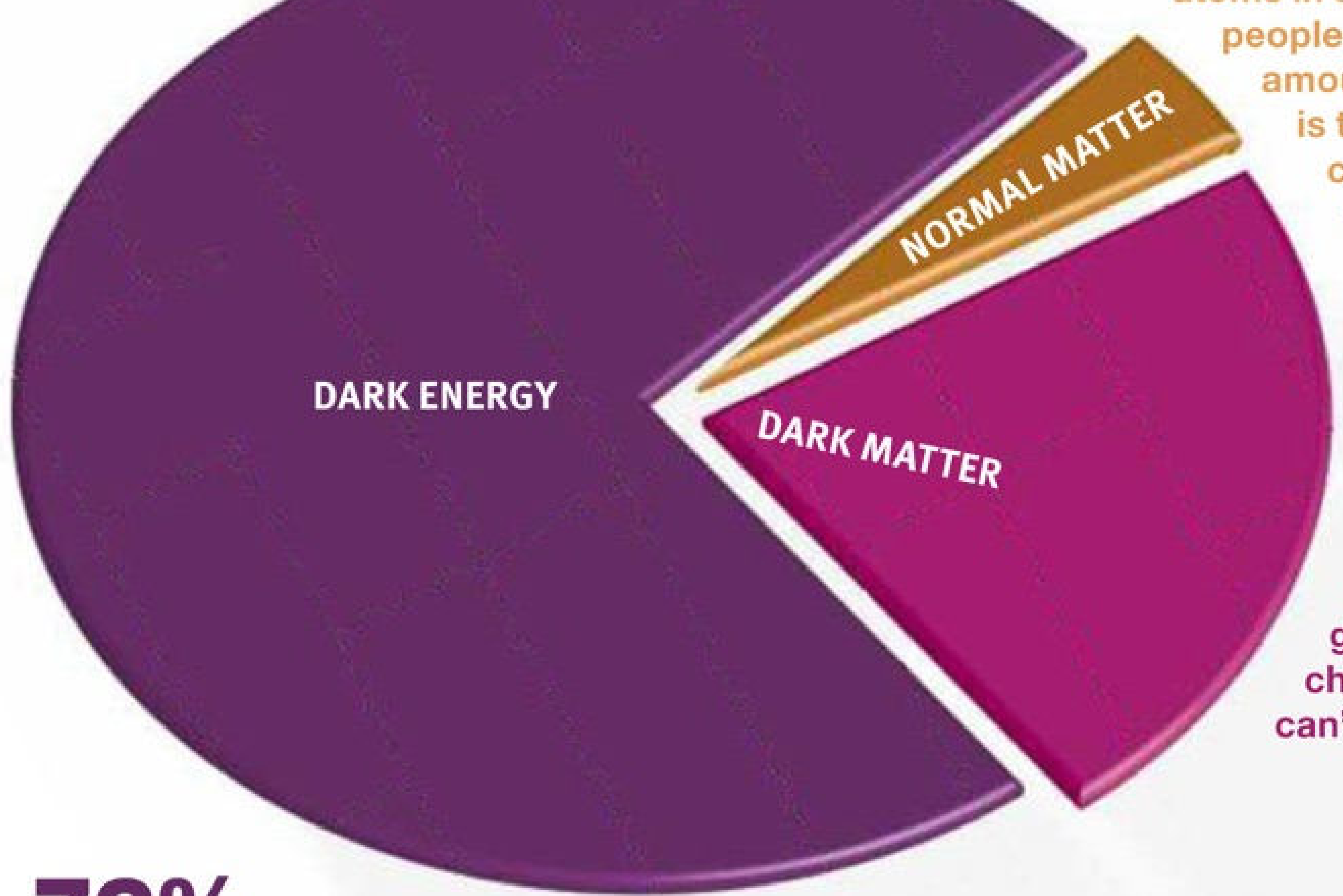
When Americans flocked to the Black Hills of Dakota during a gold rush in the 1870s, they had feverish dreams of riches beyond imagination. They certainly weren't thinking about laying the foundations for 21st century scientists to solve one of the Universe's biggest mysteries.

But later this year, a mine lying deep below those very same Black Hills will play host an ambitious experiment to try to identify 'dark matter', the mysterious, invisible substance thought to make up most of the matter in the cosmos. Deep underground, the LUX (Large Underground Xenon) detector will be attempting to solve the dark matter problem once and for all.

"Up till now, we've only been able to study less than five per cent of the total composition of the Universe in the form of the conventional particles that you and I are made of," says Rick Gaitskell, a physicist from Brown University in Providence, Rhode Island. "At the turn of the 21st century, dark matter is one of the most fundamental mysteries, and one of the keys to understanding the Universe." ▶



WHAT IS THE UNIVERSE MADE OF?



4% NORMAL MATTER
Normal matter – like the atoms in stars, planets, plants and people – makes up a very small amount of the Universe. This is the only ingredient of the cosmos that scientists fully understand.

23% DARK MATTER
Dark matter makes up roughly 23 per cent of the Universe. It must have mass to gravitationally influence stars and galaxies, but zero electric charge, explaining why it can't emit light.

73% DARK ENERGY
The largest component of the Universe is 'dark energy' (73 per cent), a mysterious energy that makes the expansion of the cosmos accelerate. Discovered in the 1990s, it remains unexplained.

SANFORD LABORATORY, BROWN PARTICLE ASTROPHYSICS GROUP X2

▶ Since the 1930s, evidence has grown that huge quantities of dark matter form vast balls centred on galaxies of stars. It's profoundly invisible and neither emits nor reflects light; scientists only know it's there because of its gravitational pull on visible stars and galaxies. For instance, stars on the outskirts of a galaxy typically orbit much faster than Newton's laws of gravity predict; without extra gravity from dark matter, those galaxies would simply fly apart. In fact, observations suggest that only around five per cent of the Universe is normal matter – the atoms that make up everything that we can see like stars and planets. The other matter is a web of invisible stuff throughout space, in which galaxies of stars are embedded like lights on a Christmas tree.

Modern theory backs the idea, too. It's difficult to explain how galaxies of stars formed in the early Universe unless dark matter acted as a choreographer, its gravity forcing normal matter to congregate into clumps that became the construction sites of star systems like our own Milky Way. Without dark matter, galaxies, the Sun and planet Earth wouldn't exist.

So what is dark matter made of? Nobody knows. But the most popular bet is that it's composed of weakly interacting massive particles, or WIMPs. They must have mass because they exert a gravitational pull, but they cannot be electrically charged; their invisibility proves they don't 'feel' the electromagnetic force. And encouragingly, these hypothetical particles also crop up in theories that could, if correct, patch up our incomplete understanding of nature's particles and forces.

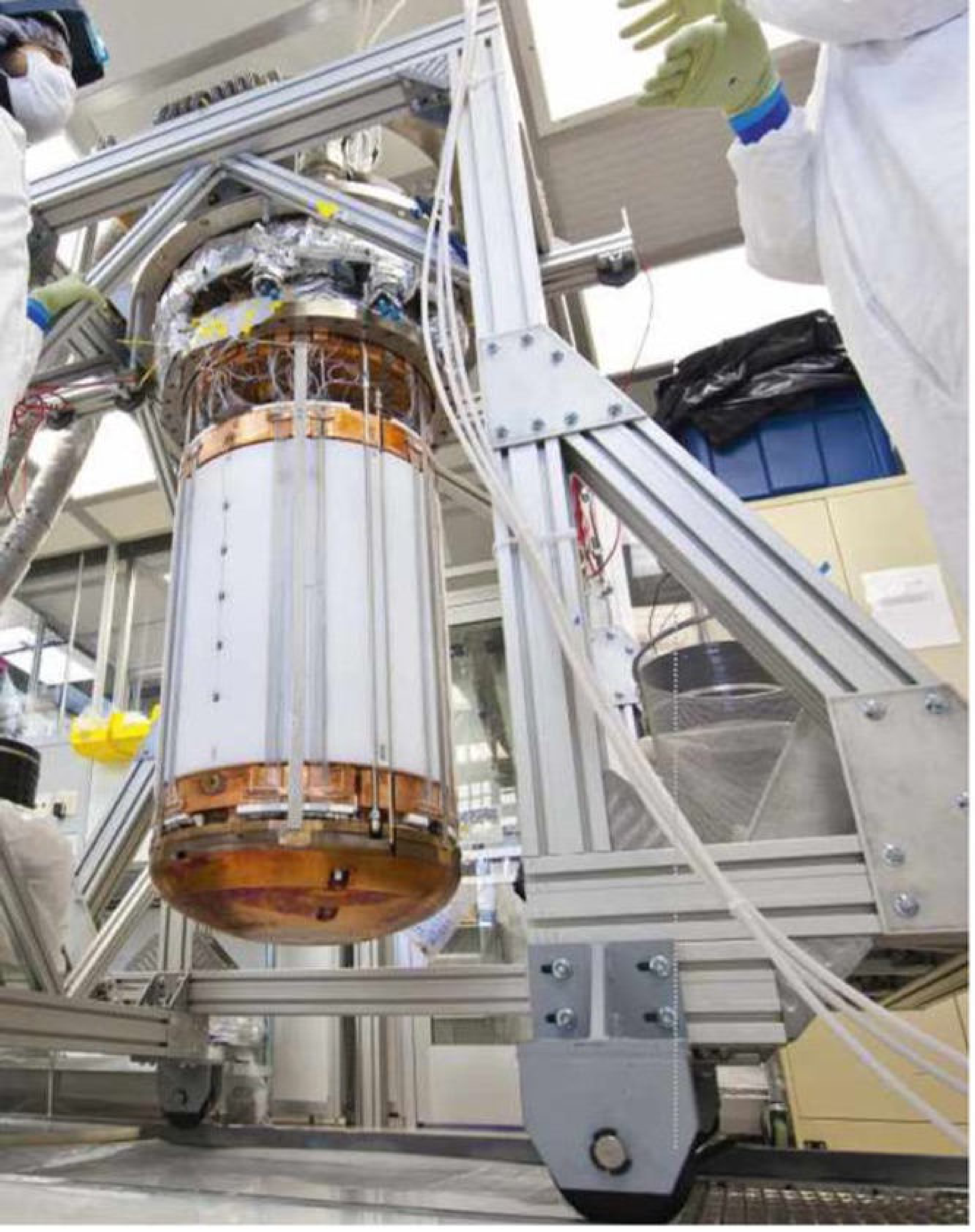
But the properties of WIMPs make them dauntingly hard to detect. They would hardly interact with normal matter, making them amazingly 'slippery'. A gale of dark matter WIMPS would be constantly battering the Earth – mostly breezing straight through it without stopping. So how do you catch a WIMP?

DARK KNOWLEDGE
Experimental limits and theoretical arguments make scientists favour the idea that dark matter particles weigh about 50 to 1,000 times as much as a proton.

Going underground

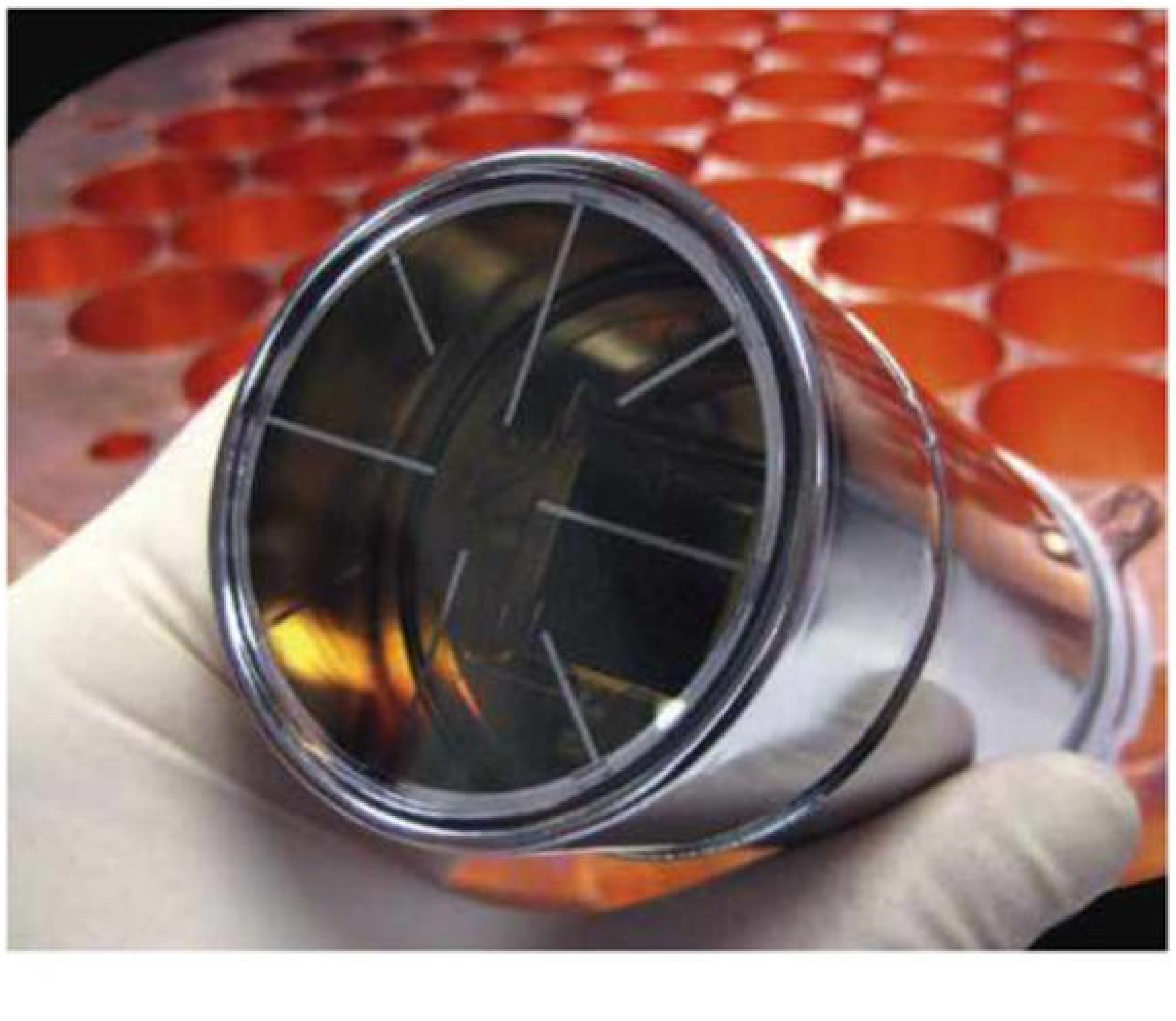
The LUX detector will take on that challenge by looking for tiny signals that a dark matter particle might trigger when it very occasionally bumps into the nucleus of a xenon atom. One of the biggest difficulties is that cosmic rays – including mundane particles like electrons and protons – constantly bombard the Earth from space and could be confused for exotic dark matter in the xenon experiment.

To get round this problem, the LUX team has set up its experiment deep in North Dakota's Homestake Mine, founded in the 1870s. Until mining operations ceased there in 2002, it was the deepest and largest gold mine in North America. The 1.5km of rock above the experiment screens out most of the background cosmic-ray 'noise'. On the Earth's surface, around three cosmic rays fly though your hand every second; in the deep cavern where LUX sits, that figure falls to only about one a year.



To keep it cool, the LUX detector is housed inside a 2m cryostat...

...which in turn is housed inside a vat containing 300 tonnes of water



Inside LUX, 122 photomultiplier tubes do the actual detecting

IS DARK MATTER A RED HERRING?

Dark matter is not the only theory to explain the Universe's missing mass

Mordehai Milgrom

Not all scientists are convinced that dark matter exists. Since the 1980s, Mordehai Milgrom from the Weizmann Institute in Israel, has backed an alternative idea – that gravity doesn't behave as we expect. Perhaps in the outskirts of galaxies, where stars experience much lower gravitational accelerations than we experience in our Solar System, Newton's theory of gravity no longer holds.

Milgrom has developed an alternative theory of gravity called 'modified Newtonian dynamics', or MOND, which can explain why stars whirl around in fast orbits in the outskirts of galaxies. It neatly predicts star speeds in many galaxies without requiring vast amounts of exotic dark matter to stop them flying apart.

However, critics argue that the MOND theory doesn't explain why galaxies clumped together in the early Universe, nor how structure evolved, as well as dark matter does. Nor can it properly account for 'missing mass' on larger scales of galaxy clusters. "MOND is indeed not perfect," Milgrom concedes. "But its extensive success on smaller scales tells us, I think, that it carries a basic truth."

He is optimistic that support for MOND will grow in future as the theory is fine-tuned. And if dark matter is a no-show in the next generation of experiments like LUX, he foresees that the hunt for it could one day seem like a wild goose chase. "Negative LUX findings will certainly help push the pendulum in the MOND direction," says Milgrom.

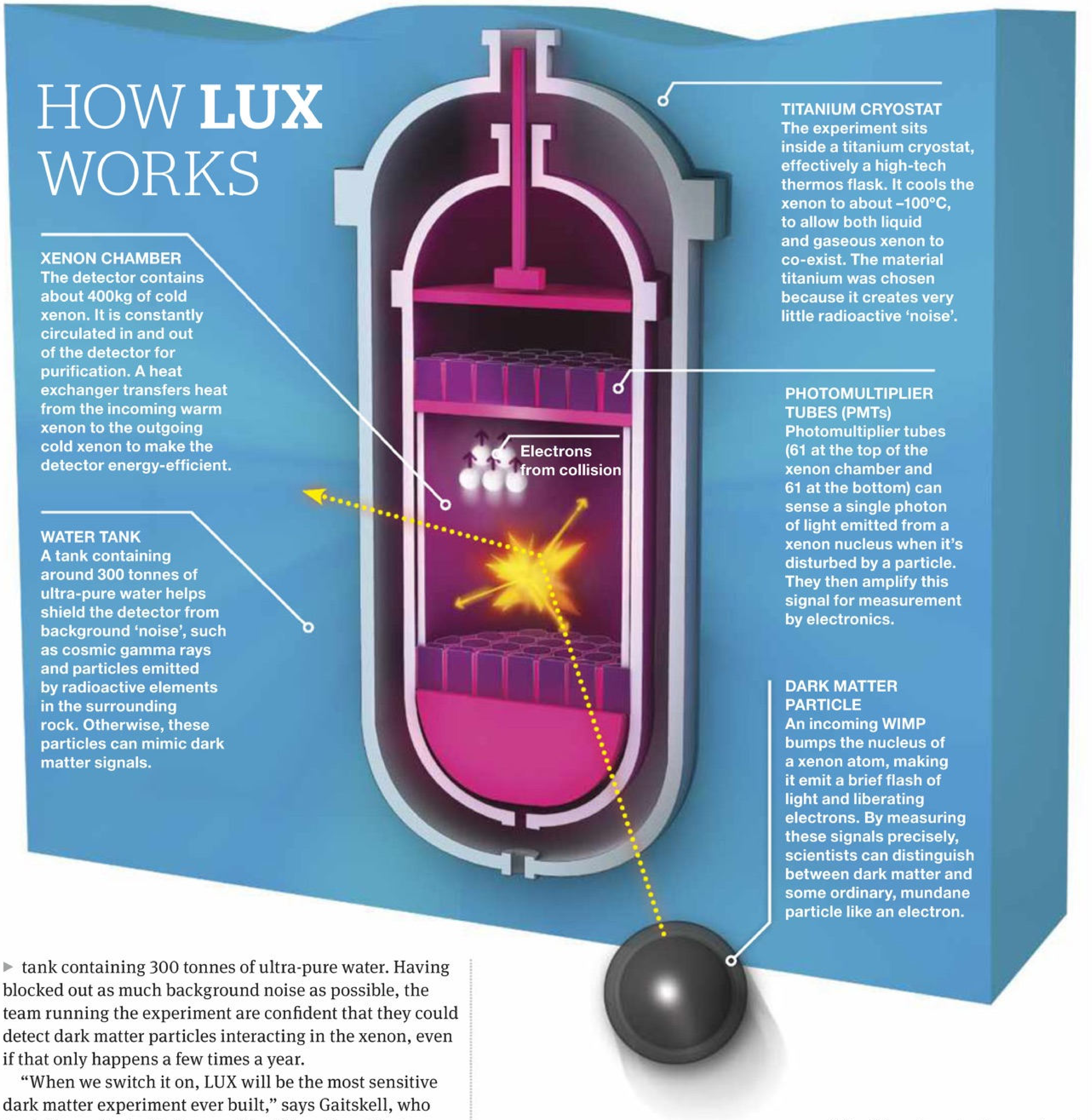
DARK KNOWLEDGE

Dark matter has no practical applications. Even if it were theoretically possible to assemble some sort of dark matter gadget, it would fall straight through the Earth.

The detector consists of a giant vat of cold xenon gas and liquid weighing a third of a tonne. It's chilled inside a cryostat nearly two metres high, a bit like a giant thermos flask. When a particle zooms into the detector, it might bump into the nucleus of a xenon atom, and this collision will release the odd photon of light as well as sprays of electrons. By detecting the light flashes and electrons, scientists can tell whether an exotic dark matter particle has passed through, or a mundane particle such as an electron or proton.

For added shielding from cosmic rays, as well as from particles released by natural radioactive decay in the surrounding rock, the LUX detector sits inside a huge ▶

HOW **LUX** WORKS



TITANIUM CRYOSTAT
The experiment sits inside a titanium cryostat, effectively a high-tech thermos flask. It cools the xenon to about –100°C, to allow both liquid and gaseous xenon to co-exist. The material titanium was chosen because it creates very little radioactive 'noise'.

XENON CHAMBER
The detector contains about 400kg of cold xenon. It is constantly circulated in and out of the detector for purification. A heat exchanger transfers heat from the incoming warm xenon to the outgoing cold xenon to make the detector energy-efficient.

PHOTOMULTIPLIER TUBES (PMTs)
Photomultiplier tubes (61 at the top of the xenon chamber and 61 at the bottom) can sense a single photon of light emitted from a xenon nucleus when it's disturbed by a particle. They then amplify this signal for measurement by electronics.

WATER TANK
A tank containing around 300 tonnes of ultra-pure water helps shield the detector from background 'noise', such as cosmic gamma rays and particles emitted by radioactive elements in the surrounding rock. Otherwise, these particles can mimic dark matter signals.

DARK MATTER PARTICLE
An incoming WIMP bumps the nucleus of a xenon atom, making it emit a brief flash of light and liberating electrons. By measuring these signals precisely, scientists can distinguish between dark matter and some ordinary, mundane particle like an electron.

▶ tank containing 300 tonnes of ultra-pure water. Having blocked out as much background noise as possible, the team running the experiment are confident that they could detect dark matter particles interacting in the xenon, even if that only happens a few times a year.

"When we switch it on, LUX will be the most sensitive dark matter experiment ever built," says Gaitskell, who leads the project with Thomas Shutt from Case Western Reserve University in Cleveland, Ohio. "If the dark matter signal shows up, it should be extremely clear."

The detector has already passed tests on the surface with flying colours. "We've had a full dress rehearsal for many months, operating the detector on the surface as if we were underground," says Gaitskell. In June, scientists and engineers installed the detector in the Homestake Mine, and it should begin gathering data in earnest by the end of 2012, or failing that, early next year.

In future, it should be possible to scale up the experiment to contain seven tonnes of xenon, giving it all the more chance of catching a fleeting WIMP. "That's 20 times larger than the current one," says Gaitskell. "We could build such an instrument and put it in the same location."

DARK KNOWLEDGE
Billions of dark matter particles may rush through your body every second. If they're 60 times as massive as a proton, about 35 would collide with a nucleus in your body each year.

The search continues

LUX is not alone in hunting for dark matter – other experiments around the world are also on the case. These include XENON100, a detector below the Gran Sasso mountain northeast of Rome in Italy. The lab sits underneath around 1.4km of rock, which cuts down cosmic rays by a factor of about a million. XENON100 uses similar technology to LUX but is smaller,

SANFORD LABORATORY, ILLUSTRATION BY FLATLINER

The Homestake Mine's Transition (left) and Davis (right) caverns will house the LUX experiment

DARK KNOWLEDGE

The amount of dark matter flooding through the Earth must be highest in June and lowest in December. This is because the Earth moves through our Galaxy and its dark matter cloud 30 per cent faster in June, owing to the Earth's to-and-fro motion as it orbits the Sun.

using about 62kg of xenon as a target for WIMPs. Various phases of the experiment have operated for several years, but so far, dark matter has not shown up.

Meanwhile, a series of experiments called CDMS (short for Cryogenic Dark Matter Search) have used a different technology down the Soudan Mine in Minnesota, which ceased mining operations in the 1960s. This experiment looks for signs of WIMPs bumping into nuclei in germanium crystals. "Alas, thus far we haven't seen any evidence for WIMPs," says Dan Bauer from Fermilab near Chicago, who is head of the CDMS research team.

In the UK, experiments at the Boulby potash mine in Yorkshire have also failed to find signs of dark matter. Occasionally, some projects, including one called DAMA/LIBRA in Italy, have reported positive evidence for WIMPs, but the overall consensus among dark matter hunters is that these purported sightings were no more than a mirage.

It's possible that LUX will come back empty-handed, too. Bauer cautions that the detector's performance is an unknown quantity until it starts running, and scientists test their ability to identify and reject mundane particles. "It may take them the rest of the year before they know how good their experiment really is," he says.

But Bauer insists the chances of finding dark matter in LUX or other detectors in the planning stage are better than ever. "Direct detection experiments are just entering the sensitivity range where most theories predict we should see something," he says. "If we don't spot something in the next generation of experiments, I will start to worry."

Ultimately, no-one can rule out the idea that dark matter is just too slippery to be detectable in any experiment scientists can dream up and realistically build. "We don't know the physics of dark matter, so you can't make any guarantees," says Gaitskell. "But I'm optimistic that we have built a detector which has a considerably better sensitivity than anything we've built before. We're extremely excited."

If all goes well, Gaitskell hopes to announce the first results from the LUX experiment in the summer of 2013. And then, the prospectors of Dakota might have something momentous to take a little bit of credit for – solving one of the Universe's best-kept secrets. ■

Hazel Muir studied astrophysics before becoming a science writer

FIND OUT MORE

http://luxdarkmatter.org
Home page for the LUX experiment

Radio 4's *Frontiers* covered the search for dark matter in November 2009. Listen to presenter Sue Nelson's visit to an underground detector in North Yorkshire at: www.bbc.co.uk/programmes/b00ny7nd

Head of research Lars Williams hard at work in the Nordic Food Lab

CLAES BECH-POULSEN

The CHEMISTRY of COOKING

For 20 years, scientists and chefs have been experimenting with ingredients to understand cuisine. **Emma Davies** gets a taste for molecular gastronomy

Sunshine and strawberries. Life doesn't get much better. Unless, that is, you add some shavings of parmesan – or put the strawberries in an ice-cold beer. Summer raspberries, meanwhile, are improved by the addition of olives.

Such odd couples share flavour compounds. The peculiar pairings are the result of analysing the flavour molecules in each food. Mixing ingredients in curious yet complementary combinations is one of many approaches to 'molecular gastronomy', a branch of food science that's 20 years old this month. It's a discipline that involves studying the physical and chemical changes that occur in cooking.

Another route to a novel gastronomic experience is to extract the compounds responsible for an ingredient's flavour, draw them out into water to create a stock, and then turn this 'food' into a gel (many foods consist of a gel-like matrix structure; see 'Q&A', p51). These gels can be adapted to give a different texture, or coloured to make them look more appetising.

French chemist Hervé This, the father of molecular gastronomy, calls this approach 'note-by-note cuisine' and likens it to composing music, with the ingredients acting as instruments. "With a synthesizer you can make any music," he says. "Artistically it is very exciting – the proposal with note-by-note is to create new food." ►

▶ Dr This co-founded the study of molecular gastronomy alongside the late Oxford University physicist Nicholas Kurti. In August 1992, they directed the world's first molecular gastronomy workshop for invited scientists and chefs. Partly motivated by chefs' heavy reliance on old wives' tales and the low level of scientific knowledge in cuisine, Kurti and This suggested that traditional kitchen techniques could be improved by understanding the physics and chemistry involved.

Heating and browning foods, for instance, starts a cascade of complex reactions that result in the rich flavours of cooked meats, roasted coffee and the golden surface of cakes. When heated, naturally-occurring sugars in the food react with amino acids (the building blocks of proteins) to produce tasty brown compounds. Named after the French chemist who discovered them in 1912, these 'Maillard reactions' can be influenced by tweaking pH (acidity level), temperature and the concentrations of proteins and sugars. Brushing buns and pastries with an egg or milk glaze boosts browning because eggs provide a good protein source, while milk contains the sugar lactose.

After Kurti died in 1998, This continued to run molecular gastronomy workshops until 2004. One of the participants was Heston Blumenthal, and today, televised cookery wouldn't be the same without the requisite temperature probes, water baths, liquid nitrogen and coloured gels.

A three-star Michelin chef, Blumenthal is famed for unusual food combinations and adding extra sensory elements such as sound recordings to the dining experience. He now distances himself from the scientific discipline, however. A statement on his website reads: "The term 'molecular gastronomy' does not describe our cooking or indeed any style of cooking."

Hervé This agrees. "There will never be any chemistry in cooking," he says. "This is a mistake I made some years ago. Chemistry is a science. The goal of science is to look for the mechanisms of phenomena."

Once in the kitchen, experimenting with food becomes 'molecular cooking' or 'molecular cuisine'. For Blumenthal, science simply helps him get the best out of ingredients. For example, careful measurement and control of temperature and cooking time results in a sublime soft-boiled egg or a lemon tart with a perfect degree of wobble – the temperature to aim for is 62°C.

Peter Barham, a polymer physicist at Bristol University and an honorary professor of molecular gastronomy at the University of Copenhagen in Denmark, helped equip the high-tech kitchen at Blumenthal's restaurant, The Fat Duck. He's dismayed whenever a new TV chef proudly proclaims their use of "molecular techniques" but then fails to use them properly, and laughs when recalling a recent show where a chef

American and western European recipes often combine ingredients that share flavour compounds

Heston Blumenthal uses science in the kitchen but rejects the term 'molecular gastronomy'

CLAES BECH-POULSEN, CORBIS, GETTY

The Nordic Food Lab has samples of countless ingredients, from the traditional to the surprising

poached food in liquid nitrogen, only to let it warm to room temperature. “A complete waste of effort,” says Barham.

But there are chefs who are experimenting with food to reinvent flavours. Chef Rene Redzepi and entrepreneur Claus Meyer, founders of Noma in Copenhagen – regularly rated the best restaurant in the world – are championing ‘new Nordic cuisine’, a cookery style that limits itself to using local, seasonal ingredients. Because this means no foreign foods, chefs are forced to recreate flavours through unusual produce and techniques.

As part of this endeavour, Redzepi and Meyer built the Nordic Food Lab, a converted houseboat that acts as test kitchen for their nearby Noma restaurant and doubles as an independent research lab for exploring Nordic cuisine. The lab’s chefs have, for example, been trying to find a new way to make fish sauce (usually created from Far Eastern ingredients) from local herring and mackerel. Their Danish fish sauce is now undergoing chemical analysis at Harvard University.

The Nordic Food Lab chefs, including head of research Lars Williams, are also collaborating with scientists at the University of Southern Denmark to share the results of their experiments. Their first paper, published in the journal *Flavour*, describes how it’s possible to develop the taste of umami (a typically Far Eastern flavour – see below) from seaweed.

CULINARY COMBINATIONS

Some years ago, Heston Blumenthal paired white chocolate and caviar through trial and error, only later discovering that they both contain trimethylamine and other complementary compounds. Tests have also shown that pork and jasmine share a molecule called indole, while chocolate and blue cheese – an increasingly popular pairing – share at least 73 flavour compounds.

‘Food pairing’ is the name that’s been given to this idea of matching ingredients based on common flavour compounds picked out by lab analysis. Food pairing throws together oyster and passion fruit (try a teaspoon of fruit with a raw oyster). Chocolate and baked onions also share flavour compounds, and many a food blog recommends putting them together.

Dr Sebastian Ahnert, a theoretical physicist at Cambridge University, has worked with colleagues to create networks of flavours by analysing 56,000 recipes from around the world. The researchers have discovered that north American and western European recipes often combine ingredients that share flavour compounds. Indeed, some common couplings, such as butter and vanilla or butter and egg, share a large number of compounds.

East Asian recipes show the opposite trend, with recipes tending to avoid ingredients with common flavours. Distinctively East Asian ingredients – such as soy sauce, rice and ginger – don’t share compounds. Ahnert’s team are now analysing new data to gain more insight into this East Asian effect. “There are strong cultural reasons for using certain ingredients,” says Ahnert.

Another explanation, Ahnert suggests, might be that East Asian cuisine relies heavily on umami. This ▶

Q&A
HERVÉ THIS

The father of molecular gastronomy on studying the science of food

Can cooking be scientific?

The big issue is that, in the lab, molecular gastronomy is science only. The idea is to produce new knowledge – it has nothing to do with cooking.

As an example, for over 10 years now we have been studying what is going on when you make carrot stock. When you put carrots into water, something escapes. We are not researching what is in the stock – we know that already. The question I am asking is how does it go out of carrots? We are looking for the mechanism.

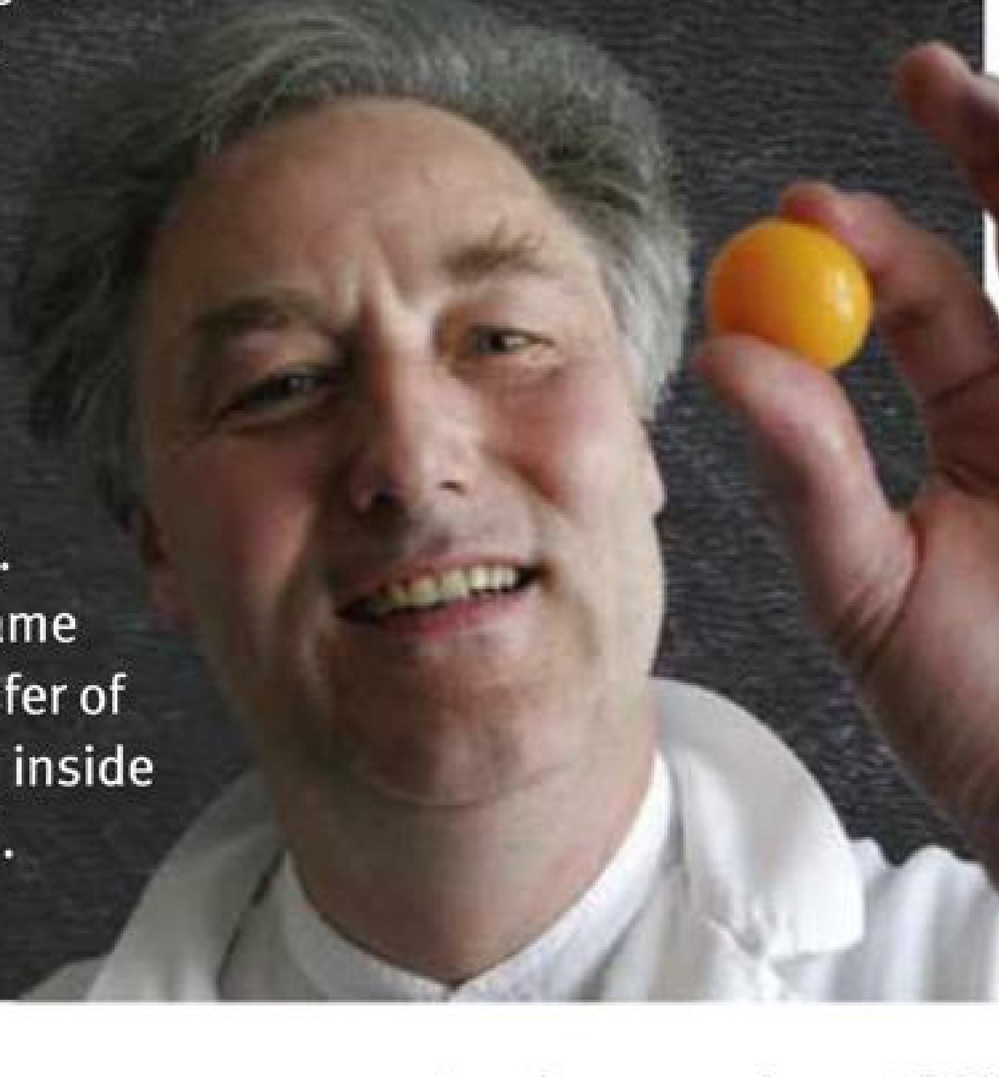
One woman in the lab is studying exactly the reverse. Suddenly we realised that when you make carrot stock something could go *in*.

What do you research?

When you have the food ingredients, in order to make a dish, you make a transformation – heating, grinding, and so on. My goal is to be able to understand how the transformation is related to the change in ‘bioactivity’. The bioactivity of a food is different to the bioactivity of the food ingredients. Compounds that are bioactive are trapped inside food and, when you eat, you release these compounds. They are released differently depending on the matrix of food. How is the release of bioactive compounds modified by the structure of food? This is one particular goal of molecular gastronomy.

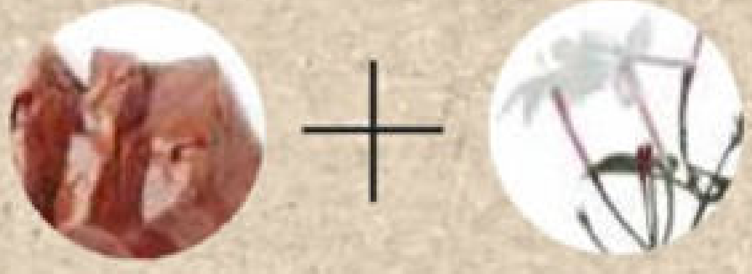
Why is bioactivity important?

Recently it has been shown that tarragon contains estragole. This compound is carcinogenic. When you apply it to cells or to rats, they get cancer. But if you give them tarragon with the same amount of estragole in it, the toxicity is reduced. If you use dried tarragon leaves, then the toxicity is zero. And when you apply pure estragole *plus* leaves, then you reduce the toxicity of the pure compound. Nobody understands the mechanism, it is very exciting. It’s always the same question of transfer of compounds both inside and outside food.



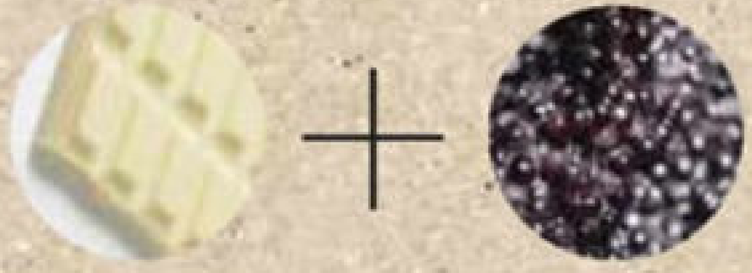
MIX N' MATCH

Strange pairs of flavours that taste good together



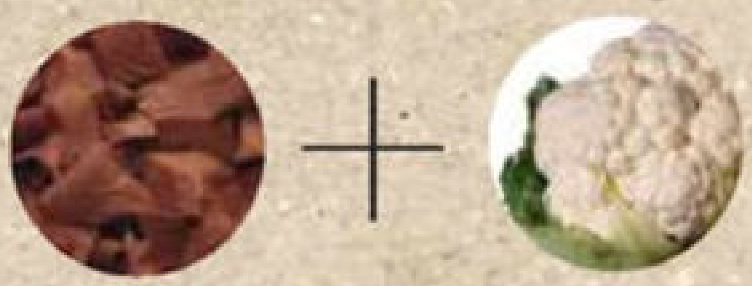
PORK LIVER AND JASMINE

These foods both contain a chemical called indole. The combination was dreamt up by François Benzi, a chemist at Swiss flavour and fragrance company Firmenich, who came up with the idea at one of Hervé This's molecular gastronomy workshops.



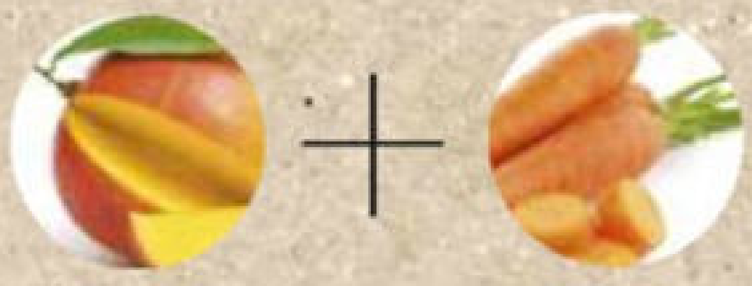
WHITE CHOCOLATE AND CAVIAR

Heston Blumenthal tried pairing these while hunting for something salty to go with chocolate. François Benzi then found that they share nitrogen-containing compounds called amines, with trimethylamine being the key compound that links the two foods.



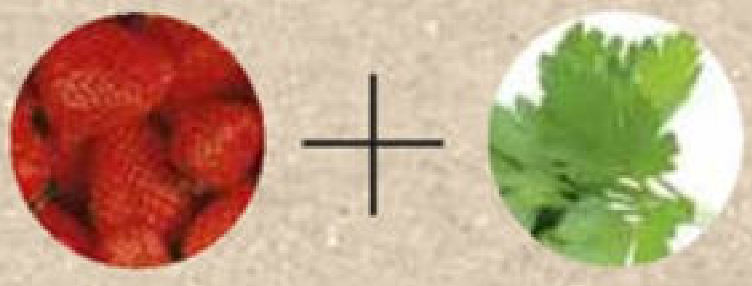
CHOCOLATE AND CAULIFLOWER

As any chocoholic gourmet will tell you, cocoa can be added to numerous savoury dishes to enrich flavour. Chocolate and cauliflower work particularly well together, as do chocolate and fried onions, thanks to pairings of sulphur-containing compounds.



MANGO AND CARROT

Another of Blumenthal's pairings, this works because both ingredients share flowery compounds known as ionones, commonly used in perfumes. Beta-ionone, which forms when the carotene compounds that give carrots their colour break down, is also found in mango.



STRAWBERRIES AND CORIANDER

Strawberries are highly versatile and are sometimes described as being interchangeable with tomatoes in recipes. Strawberries and coriander share aroma compounds including hexenal and linalool, an alcohol found in many flowers and spice plants.

*Are you tempted to try any of these food combinations? Email **post@sciencefocus.com** and tell us how you get on!*

▶ savoury mouth-filling sensation is perhaps best known through monosodium glutamate (MSG), which is added liberally to many a Chinese takeaway. Ahnert suggests that different types of glutamate may work in synergy to enrich the umami effect.

Some ingredients are naturally rich in glutamate. For example, food scientists from Reading University worked with Blumenthal to discover that tomatoes have far more glutamate in the jelly surrounding the seeds than in the flesh. The seeds, which are traditionally left out of many UK recipes, can therefore add a richness to sauces.

Ahnert, who enjoys applying science to his home cooking and loves Hervé This's signature chocolate mousse (melt chocolate with water and whisk while cooling over ice) is seeking answers to seemingly simple yet sophisticated questions: why do we perceive some flavours as complex, and why do we prefer some flavours to others? His hunch is that the answers could lie in the complexity of the brain's response to flavours, as we create flavour images when sensory receptors in the nose are activated by flavour compounds. "Could it be that more delicious things excite many more receptors?" he asks.

Chocolate and coffee, for example, have so many flavour compounds that they're more likely to excite a multitude of different receptors. Coffee is so complex that it goes with a lot of things, including meat, says Ahnert. "You can think of coffee as a substitute for stock – a complex mixture of compounds that binds ingredients together."

THE APPLIANCE OF SCIENCE

Like Ahnert, Peter Barham is fascinated by flavour perception. He considers molecular gastronomy to be the science of why some food tastes terrible, some good and some delicious, and is developing questionnaires to predict whether someone will like a given dish.

"If you're running a restaurant or planning a dinner party, the ideal

Peter Barham of the University of Bristol helped kit out The Fat Duck's kitchen

DR A A LOUIS, UNIVERSITY OF BRISTOL

FOOD ON THE BRAIN

How we perceive flavour isn't determined just by what touches the tongue – it's also influenced by what happens in the brain

'Flavour' is actually as much about scent as it is about taste

A meal at a fine restaurant will often seem to taste better than food eaten off a paper plate with plastic cutlery. This is because our perception of the quality of food and drink doesn't only involve the senses – emotions, memories and expectations all play a role too. Colour can also affect how we perceive flavour. In one famous French study, connoisseurs were convinced they were drinking red wine when it was, in fact, white wine dyed red.

Eating and drinking is the only activity that involves all our core senses. The most important are the chemical senses: taste, smell and chemesthesis – the chemical sensibility of body surfaces. Perhaps suprisingly, only about 20 per cent of flavour perception comes from the tongue, where there are taste receptors for sweet, salty, sour, bitter and umami (Japanese for 'pleasant, savoury taste').

Flavour perception comes mainly from smell, and for us to smell chemical compounds they need to be volatile – to travel through the air. When chewing food, we pump volatile molecules to olfactory (smell) receptors in the nose. "This retronasal smell is key to everything when you are eating," says Professor Gordon Shepherd of Yale University.

Humans have several hundred different olfactory receptors in the nose. These receptors – proteins with a pocket for binding odour molecules – sit on the surface of cells. Each cell carries only one type of receptor, which can only detect a limited number of odour molecules. When a molecule binds to a receptor, it triggers its cell to send nerve impulses to the olfactory bulb, a region of the brain behind the eyes. Cells carrying the same type of olfactory receptor send impulses to the same part of the olfactory bulb. Once activated, the olfactory bulb sends impulses to other brain regions.

"The brain creates flavour from the molecules in the food," says Shepherd, who works on 'neurogastronomy' – the study of how all aspects of flavour perception are tied together in the brain. As most smells are composed of multiple odour molecules and each molecule can activate several receptors, a pattern forms in the brain. "We call this an odour image – it is processed to the highest levels in the brain where perception occurs," says Shepherd.

US food scientists Richard Axel and Linda Buck won a 2004 Nobel prize for their work on odour perception, showing that three per cent of our genes code for the different olfactory receptors.

would be to provide a questionnaire in advance," says Barham. "Then you could produce a meal that is nutritious – with the right balance of nutrients for an individual's state of health – and delicious, so that they really enjoy eating it and are satisfied afterwards." He's now working on a project with a restaurant in Bristol to see how "modifying the sensory experience" affects diners' appreciation of the food.

Professor Gordon Shepherd, a neurobiologist at Yale University in the USA, is also studying flavour perception. His work is in 'neurogastronomy', the science of how the brain creates flavours (see 'Food on the brain', above). Shepherd says he's partly driven by a desire to help fight obesity. "The more we understand about how the brain creates flavour, the more it will help us to understand how to encourage healthy diets," he says.

Physicist Sebastian Ahnert (right) is a big fan of This's work

Food cravings activate similar brain regions to drug and alcohol addiction. Research into overeating and obesity, says Shepherd, should look at how the brain responds to fats, sugars and proteins – but also flavours. "The fact that so many of our flavour preferences are learned suggests we have to start at an earlier age to help kids understand what are healthy flavours and what are the flavours that they need to resist."

Applying the science of cuisine could also help schoolchildren learn more about nutrition than they currently pick up in home economics. Barham suggests chemistry and physics lessons where practical experiments involve some cooking. "The kids would learn to cook and we could end up with a generation of people who know how to cook from basic ingredients, and are therefore much less likely to be obese."

> *"You can think of coffee as a substitute for stock"*

In the meantime, molecular gastronomists like Hervé This will continue to investigate how molecules interact to produce the flavours and textures in food, with the aim of creating novel eating experiences.

"Tradition is laziness," says This. "Let's move to something new." ■

Dr Emma Davies is a science writer and former food scientist

FIND OUT MORE

www.foodpairing.com
Combine ingredients in unusual ways

Neurogastronomy: How The Brain Creates Flavor And Why It Matters
by Gordon Shepherd (Columbia, 2011)

blog.khymos.org
Food blog on molecular gastronomy

10 THINGS YOU DIDN'T KNOW ABOUT SLEEP

Ever wondered what your body's doing while you're off in the land of nod? David K Randall delves into the science of snoozing

ALAMY, THINKSTOCK, GETTY X5, PRESS ASSOCIATION IMAGES, NATUREPL.COM, SUPERSTOCK

▲ ARTIFICIAL LIGHTS HAVE CHANGED OUR NATURAL SLEEPING PATTERNS

Without them, we would sleep in two blocks each night. We would fall asleep around 10pm and wake up a few hours later, going back to sleep after an hour. Psychologist Thomas Wehr found people revert to sleeping this way if isolated from artificial lights for more than a few weeks.

◀ 264 HOURS IS THE LONGEST DOCUMENTED STRETCH THAT ANYONE HAS STAYED AWAKE

In 1964, a San Diego student named Randy Gardner stayed awake without any kind of stimulants for 11 days, experiencing phantom sounds and visions the longer he went without sleep. When he finally fell asleep, he slept for nearly 15 hours. No long-term ill effects were reported.

▲ SOME ANIMALS ONLY SEND HALF THEIR BRAIN TO SLEEP

In dolphins and whales, for instance, this gives them the ability to surface for air and be on the lookout for danger while still technically sleeping. Ducks are also able to sleep with one eye shut and one-half of their brains asleep, allowing some of the birds to stand watch while others in the group rest.

▲ CHILDREN AROUND THE WORLD HAVE VASTLY DIFFERENT SLEEP PATTERNS

Jodi Mindell of the Children's Hospital of Philadelphia and Avi Sadeh of Tel Aviv University found that 95 per cent of babies in Vietnam sleep in their parents' bed, compared to 15 per cent in Australia. In New Zealand, the average bedtime for an infant is 7.30pm; in Hong Kong, it's 10.30pm.

▶ DREAMS TEND TO FOLLOW WELL-DEFINED PATTERNS

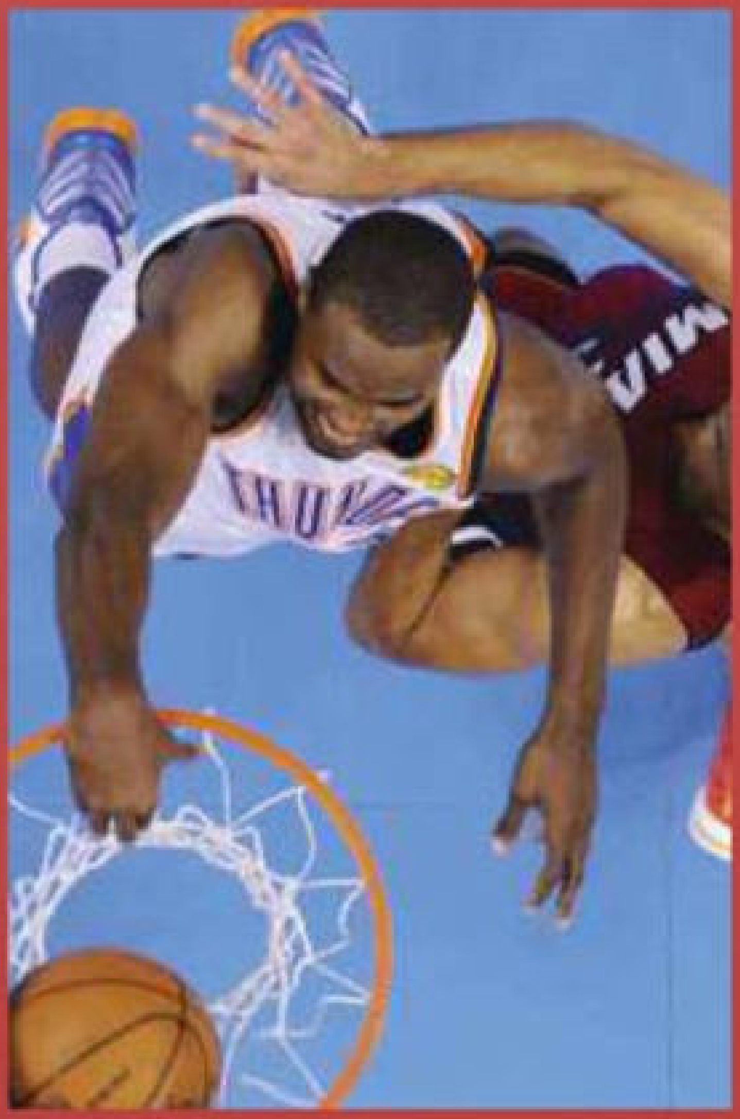
In his lifetime, Calvin Hall, a psychology professor at Case Western Reserve University in Cleveland, collected more than 50,000 dream reports from anyone who'd share them. Using Hall's database, researchers identified that we tend to dream about the things that make us anxious. Adults tend to dream about other adults, while children are more likely to dream of animals.

▲ SLEEP MAY HELP US TO LEARN NEW SKILLS

After having people play the video game Tetris before they went to sleep, Robert Stickgold of Harvard Medical School found that test subjects tended to dream about the game that night. Those subjects who dreamed about the game showed the most dramatic improvement once they played it again the next day.

▲ THERAPY MAY BE A BETTER TREATMENT FOR INSOMNIA THAN SLEEPING PILLS

Psychologist Charles Morin of Laval University in Quebec found that people who used cognitive behavioural therapy to deal with sleepless nights reported much better overall sleep quality than those treated with sleeping pills alone.



◀ SLEEPING RHYTHMS CAN AFFECT SPORTS PERFORMANCE

Researchers at Stanford University and the University of Maine found that circadian rhythms – the natural cycles that govern when we're awake and when we're sleepy – have an 'outsized effect' on professional sports: athletes at their peak circadian rhythms have an unseen advantage over their opponents.

▲ FEMALE SLEEP IS THE KEY TO A HAPPY MARRIAGE

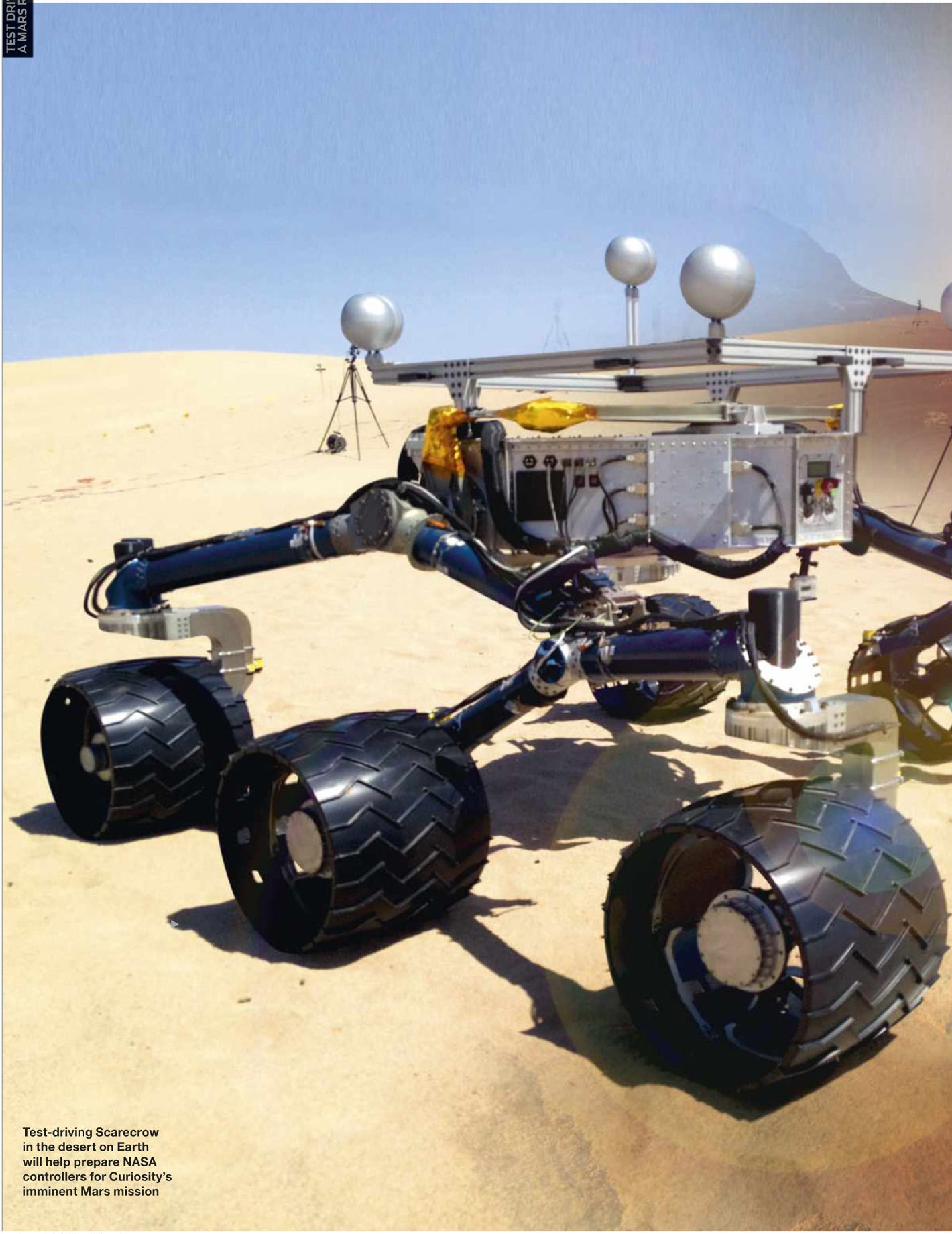
Psychiatrist Wendy Troxel of the University of Pittsburgh recently found that a woman's ability to fall and stay asleep had a greater impact on marital satisfaction than her daily interactions with her husband. The same effect was not found for men in relationships.

▶ 16-19°C IS THE IDEAL TEMPERATURE FOR A GOOD NIGHT'S SLEEP

Research in Lille, France arrived at this figure for someone sleeping in pyjamas and covered by sheets. If they sleep naked, the ideal temperature jumps to 30-32°C.

David K Randall's book* Dreamland: Adventures In The Strange Science Of Sleep *is published in September

BBC TWO **The two-part series *Goodnight Britain*, featuring a range of experiments to improve our sleep habits, airs on BBC One this autumn.**



Test-driving Scarecrow in the desert on Earth will help prepare NASA controllers for Curiosity's imminent Mars mission

NASA/JPL

GROUND CONTROL

With NASA's latest rover due to touch down on Mars in August, **Paul Sutherland** reveals why its doppelganger here on Earth is crucial for the mission's success

This month, providing it survives a dramatic descent from the skies, a Mini Cooper-sized rover like the one pictured is due to start trundling around Mars. The Curiosity rover, part of the Mars Science Laboratory, is the latest US mission sent to the Red Planet on a search for signs of life. But seen in this picture is Scarecrow – the twin that stayed home.

The Mars team at NASA's Jet Propulsion Laboratory has been rehearsing for the mission by taking Scarecrow for a spin in California's Mojave Desert and tracking its movements with an array of cameras. The sandy conditions in the Dumont Dunes are thought to resemble those in Mars's Gale Crater, where Curiosity is due to land on 6 August. The rover will be lowered to the surface by tether from a hovering descent stage – a spectacular new technique employed because Curiosity, five times heavier than its Mars rover predecessors Spirit and Opportunity, is too massive to bounce in on airbags.

Scarecrow is not an identical twin. It has been stripped of the science payload that Curiosity carries so that its weight corresponds to that of the rover on Mars, where the force of gravity is a third less. And without ►

FACT FILE: CURIOSITY

Size: 3m long, 2.7m wide and 2.2m high
Weight: 900kg (on Earth)
Size of wheels: 50cm diameter
Max speed: 4cm per second on flat ground (0.14km/h)
Landing date: 6 August 2012
Expected duration of mission: One Mars year (687 Earth days)

▶ the electronics that allow Curiosity to make decisions for itself, Scarecrow has no 'brain' – just like its namesake in *The Wizard Of Oz*.

Engineer Jaret Matthews says: "Because Mars is so far away, we made Curiosity semi-autonomous. A signal would take 20 minutes at best to reach Mars, and any signals back would take a similar time. If Curiosity has a cliff coming up and we hit the stop button, it's too late. So what we do is make a plan for the day and set a goal for the rover. We say, 'Next time we hear from you we'd like you to be at a certain location,' and that can be 150m away. Then it plans its own path, avoiding obstacles to keep itself safe. If it gets confused, it will simply stop and wait for more instructions."

Curiosity is three metres long and its six-wheeled design is derived from that of Spirit and Opportunity, which reached Mars in January 2004. But instead of solar panels, it gets its power from a radioisotope that will keep it alive for at least a full Mars year (that's 687 Earth days), during which time it will take stereo photos of its surroundings and dig into the soil to look for organic material.

Matthews adds: "Scarecrow has the same dimensions as Curiosity, but has just what it needs to ensure mobility, such as the wheels, steering and suspension. Because we got it to weigh what Curiosity will on Mars, it should have similar performance and climb hills just as well."

The stand-in rover happily tackled angles of 15 degrees on soft sand. Experience gained from driving it will help the team rescue Curiosity from any sand traps if it happens to get stuck. But Scarecrow also showed just how robust the design is.

"We really couldn't find a way to stop Scarecrow, as long as we could go downhill," says Matthews. "We would drive into these dunes until the wheels were buried up to their axles in sand, then extract ourselves instantly just by driving backwards."

Let's hope its twin brother handles equally well on Mars.

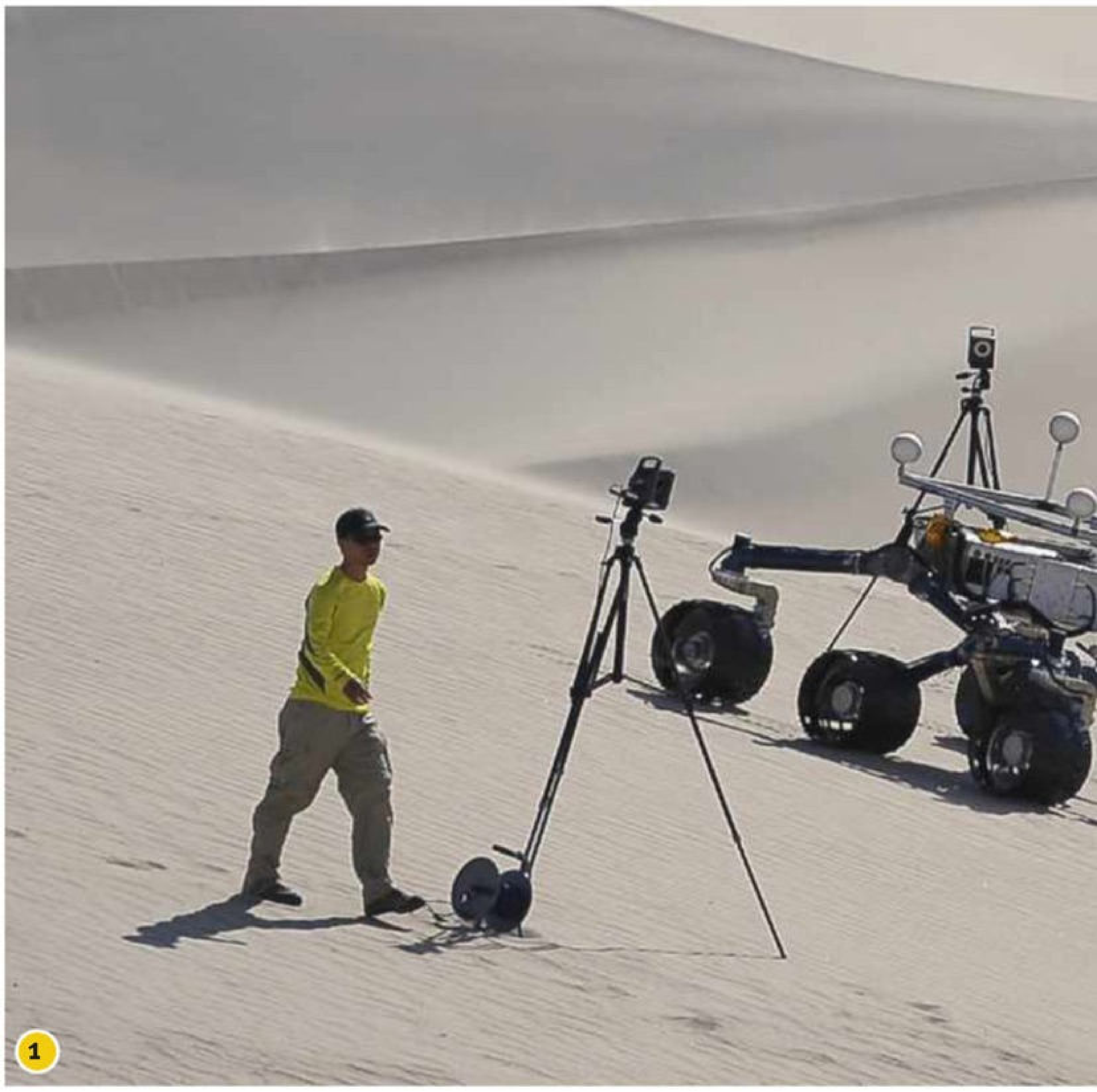
REUTERS, EYEVINE X3

① Scarecrow is tracked as it tackles a slope on one of the dunes. The JPL team pushed it to an incline of 22° in tests, but will try to keep Curiosity below 12.5° on the Martian sand.

② JPL robotics engineer John Leichty monitors Scarecrow's position in the upper screen while driving the rover with the laptop on his knee. The black rack holds motion-tracking gear. Scarecrow can also be steered via wi-fi using an iOS or Android device.

③ Matt Roman of Malin Space Science Systems tests a prototype of MASTCAM. This stereo imager is one of a number of cameras that the company built for Curiosity, and will make 3D maps of the dunes. James Cameron, director of *Titanic* and *Avatar*, is part of the MASTCAM science team.

④ The desert becomes a car park as NASA's Mars team carries out tests. Right of centre is the Surface System Testbed Lite, a mini-Scarecrow that stood in for Opportunity and Spirt. Comparing how SSTL performs to the experiences of the actual Mars rovers helps plan for new missions.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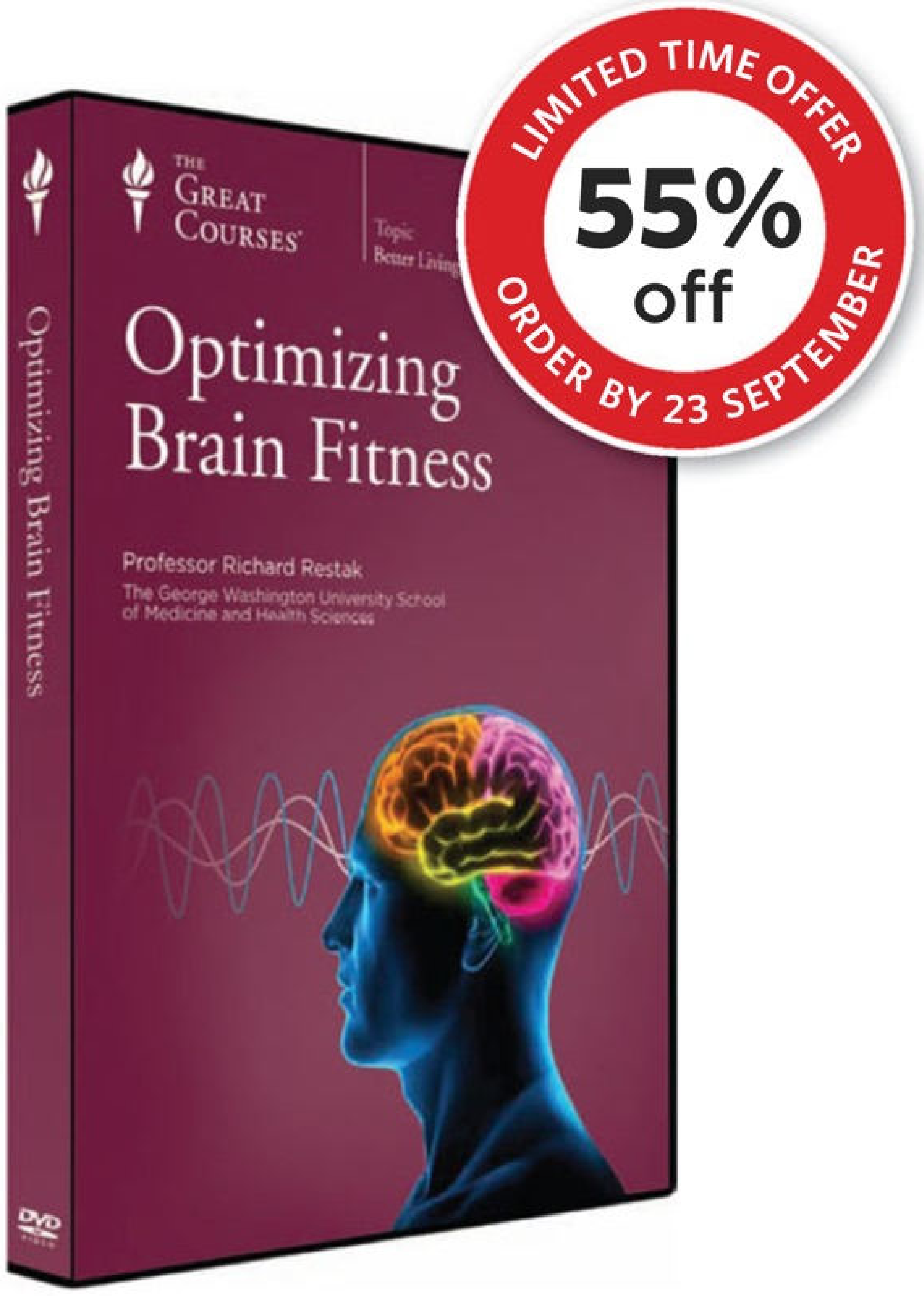

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CORBIS OUTLINE

Ben Miller

The comedian and former physicist tells JV Chamary about his new book, the funny side of science and why he changed career

Focus: **How did you first become interested in science?**
Ben Miller: My father was always interested in science, and physics particularly. He was an academic and although his field was American literature, he encouraged me to read Bertrand Russell's *Introduction To Mathematical Philosophy* and to read about quantum physics and relativity.

I wanted to go to Cambridge because if you're interested in physics then the Cavendish Laboratory is the place to go – it's where so many scientific discoveries were made – and at the time [1985] there had been a fascinating documentary about Stephen Hawking and his research. You can't study a single subject at Cambridge, you have to study all the sciences, and that opened my eyes to other areas that I hadn't taken much notice of up until university.

F: **You started a PhD in physics. What did it involve?**
BM: At the time there was a lot happening in the semiconductor physics group at the Cavendish Laboratory. We were at the point where we could start to build electronic devices that used quantum mechanical behaviour. My former supervisor Professor Pepper is still doing amazing stuff with small quantum devices. That has become a huge area of promise, because quantum computing looks like the direction that electronics is heading in. It was very exciting to be part of that at an early stage.

F: **Why did you eventually choose comedy over science?**
BM: I never used to get any applause when I arrived at the lab! I loved science but it was never my intention to do it as a career. So I was looking out for something to do with either music or acting. Then I stumbled across The Footlights, a group at Cambridge University – it's a society for comedy where you write and perform sketches. I always loved comedy so that seemed like the thing to do. So I've had this bizarre life where my day job is actually doing comedy and science has largely been a hobby.

F: **Your book *It's Not Rocket Science* is aimed at a general readership. Why did you decide to write it?**
BM: The book is a 'gateway drug' to harder science. I set out to write the kind of book I would like to read. It's for somebody who hasn't yet started reading popular science, or who has a very emergent interest. Someone who perhaps has just heard about mapping the genome or the Large Hadron Collider, and wants to get an introduction to science as a whole. It's my favourite bits explained to somebody who hasn't done science since GCSE.

But I've also got one eye on the person who did study science – even professional scientists, who tend to be very specialised. It's meant to be entertaining, but I do talk in detail about general relativity and string theory, things like that. Most scientific teaching is done from first principles: we usually build somebody up from a basic understanding to more advanced, interesting stuff. I wanted to *start* with the interesting stuff, then fill people in on a need-to-know basis.

F: **What most surprised you while writing the book?**
BM: The advances we've made in the biological sciences. It really is incredible: we can look at somebody's DNA and tell so many things about us as a species, that we had our start in Africa and pretty much the exact path of our migration around the globe.

One thing that fascinated me was what we've discovered about our ability to digest cow's milk. When you really start thinking about it, it's an extraordinary thing that full-grown great apes live off the milk of cattle. That's extremely bizarre: if you came across a group of squirrels in a woodland glade milking a badger, you'd be disgusted. We've found key bits of DNA that seem to be involved in turning on and off our ability to drink milk as adults. That mutation has occurred during civilisation, after the invention of agriculture. We tend to think of evolution as something that happens to other species, but it's happening to us.

> "The book is a gateway drug to harder science. I set out to write the kind of book I would like to read"

F: **Do you think science is funny?**
BM: I find the whole thing amusing. Some of the most intelligent people in our society give up any prospect of making much of a living in order to devote themselves to expanding human knowledge, using what you'd think would be quite a blunt instrument: testing it.

It's extraordinary what we've managed to build, just on the basis of thinking. The essential method of science is: "I think the world is like this… actually, tell you what, I'm going to go and have a look."

F: **Do scientists and comedians have anything in common?**
BM: The main thing they have in common is a scepticism about the world. I don't think you'd find many comedians that believe in astrology, put it that way. A comedian is always sceptical about other peoples' motives and articles in newspapers, and a scientist is attempting to add to the sum of human knowledge.

You could say they're both quests for some kind of sceptical truth. Scientists can't take what they see at face value, and neither can the comedian. I think that's the similarity. They're both rascals: a scientist wants to prove everyone else wrong, and the comedian wants to prove everyone else wrong, and make them laugh at the same time. ■

***It's Not Rocket Science* by Ben Miller is published by Little, Brown (£12.99)**

GROW YOUR OWN BODY

Biological engineers have started growing human body parts in the lab, enabling surgeons to replace damaged tissues with a patient's own cells. **Ruth Williams** gets under the skin of regenerative medicine

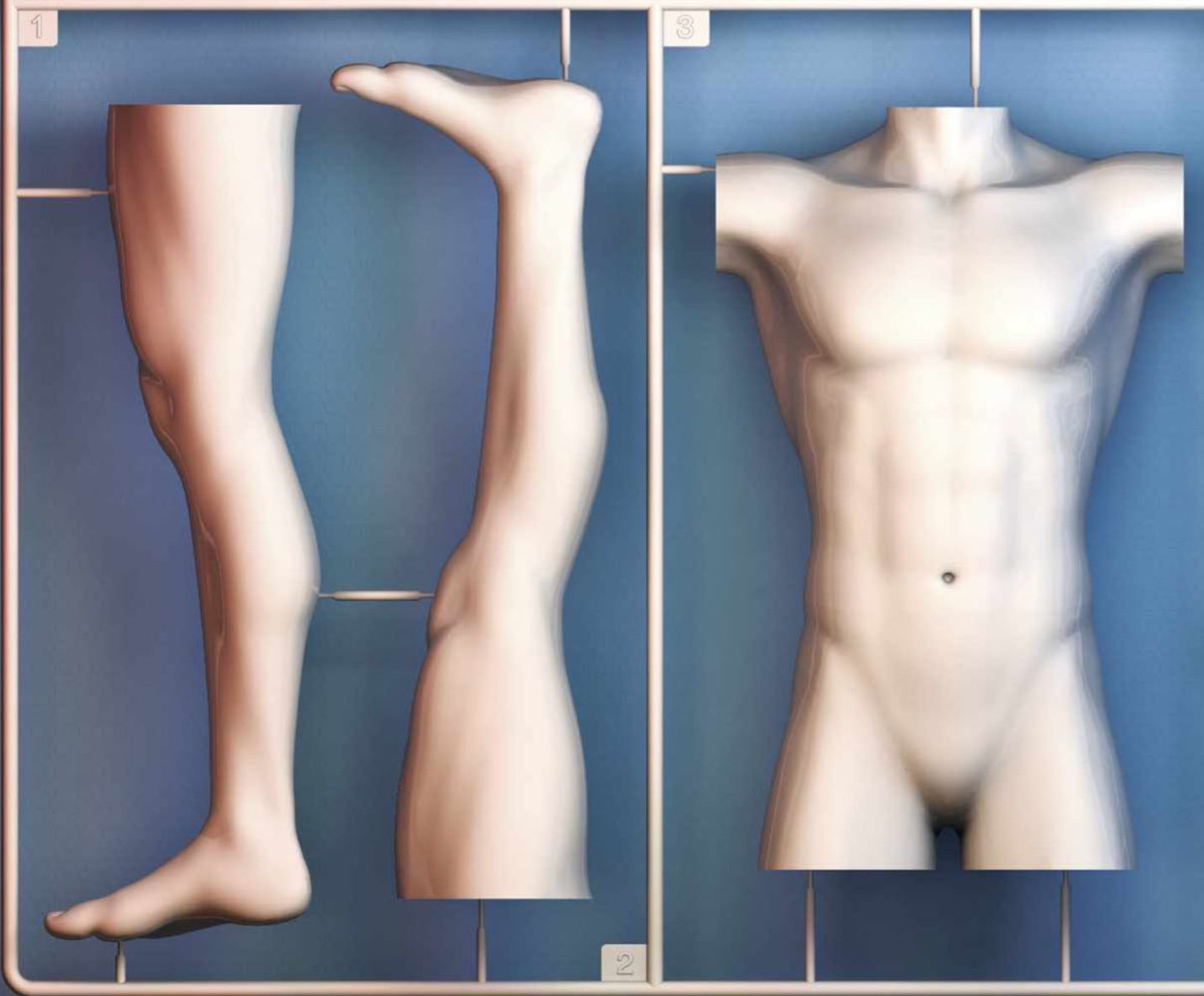
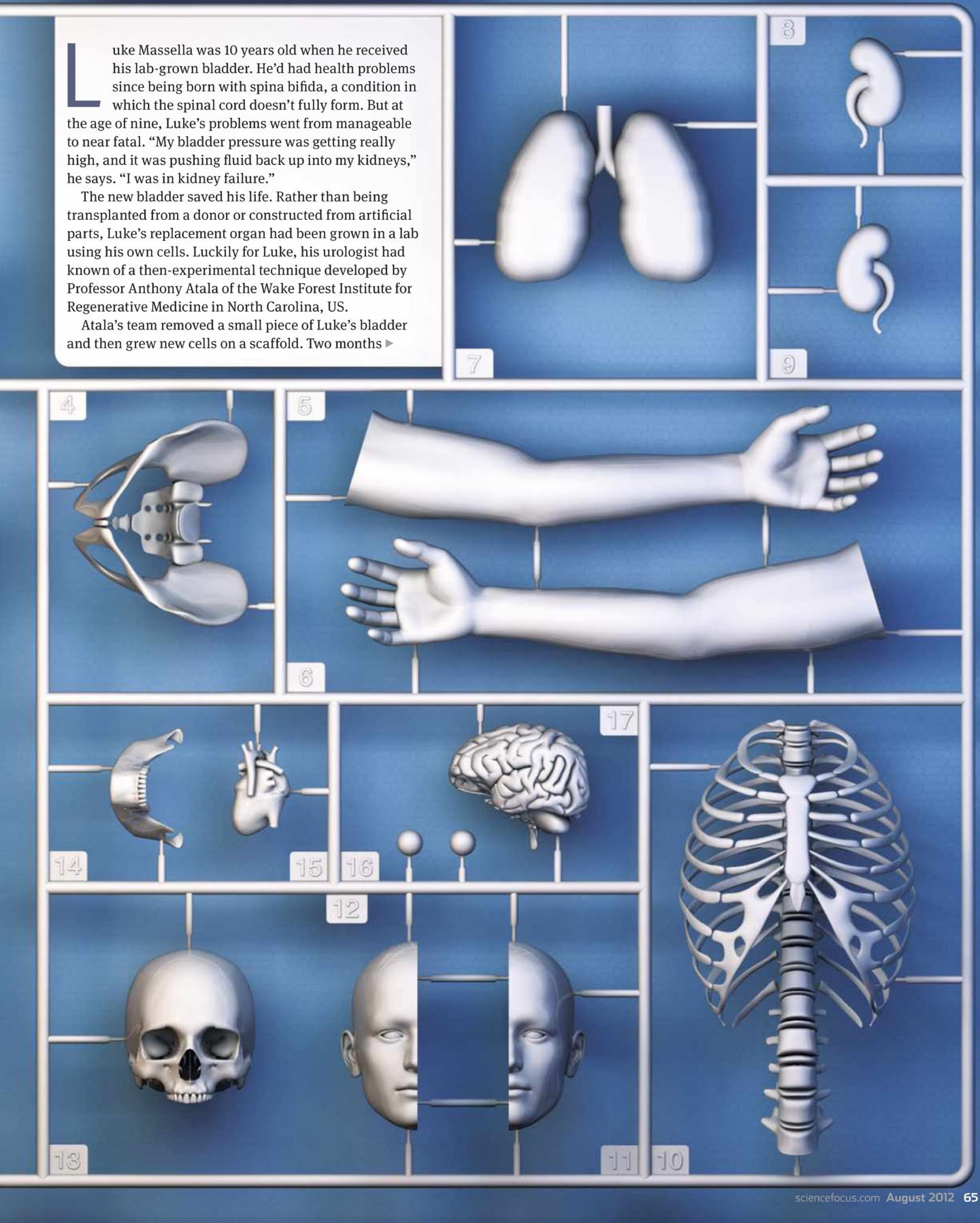


ILLUSTRATION BY MAGICTORCH

Luke Massella was 10 years old when he received his lab-grown bladder. He'd had health problems since being born with spina bifida, a condition in which the spinal cord doesn't fully form. But at the age of nine, Luke's problems went from manageable to near fatal. "My bladder pressure was getting really high, and it was pushing fluid back up into my kidneys," he says. "I was in kidney failure."

The new bladder saved his life. Rather than being transplanted from a donor or constructed from artificial parts, Luke's replacement organ had been grown in a lab using his own cells. Luckily for Luke, his urologist had known of a then-experimental technique developed by Professor Anthony Atala of the Wake Forest Institute for Regenerative Medicine in North Carolina, US.

Atala's team removed a small piece of Luke's bladder and then grew new cells on a scaffold. Two months ▶



▶ later, the old bladder was removed and replaced with the lab-grown organ. And it's been serving him well ever since, says Luke, now 21. "It was probably much harder for my parents to decide to go ahead with this experimental surgery – I just wanted to get better and get back to school, sports and friends."

If we need a new hip or hand, we would normally have to build an artificial one. If we need a new heart or liver, we transplant the organ from a person who's recently died. But while organ transplants and prosthetic body parts have saved many lives, they're not a perfect solution. With transplants, for instance, there simply aren't enough to go round: in the UK, the average waiting time for a heart transplant is about five years, for a lung it's over 14 years. And even if a patient is lucky enough to receive an organ from a donor, they face a lifetime on immunosuppressive drugs to prevent it being rejected as foreign tissue.

To sidestep such complications, researchers are busy developing alternative approaches through regenerative medicine – techniques that aim to repair or regrow a patient's diseased or damaged body parts. While tissue engineers like Atala are able to grow almost every organ in the body, from livers, kidneys and hearts right down to anal sphincters, other scientists are transplanting stem cells into damaged tissues and even reprogramming a patient's cells to repair their own organs.

"Regenerative medicine offers the promise of curing disease, rather than just treating symptoms," says Atala. "Whether it involves building replacement organs or developing cell therapies to promote healing, the ultimate goal is to improve function."

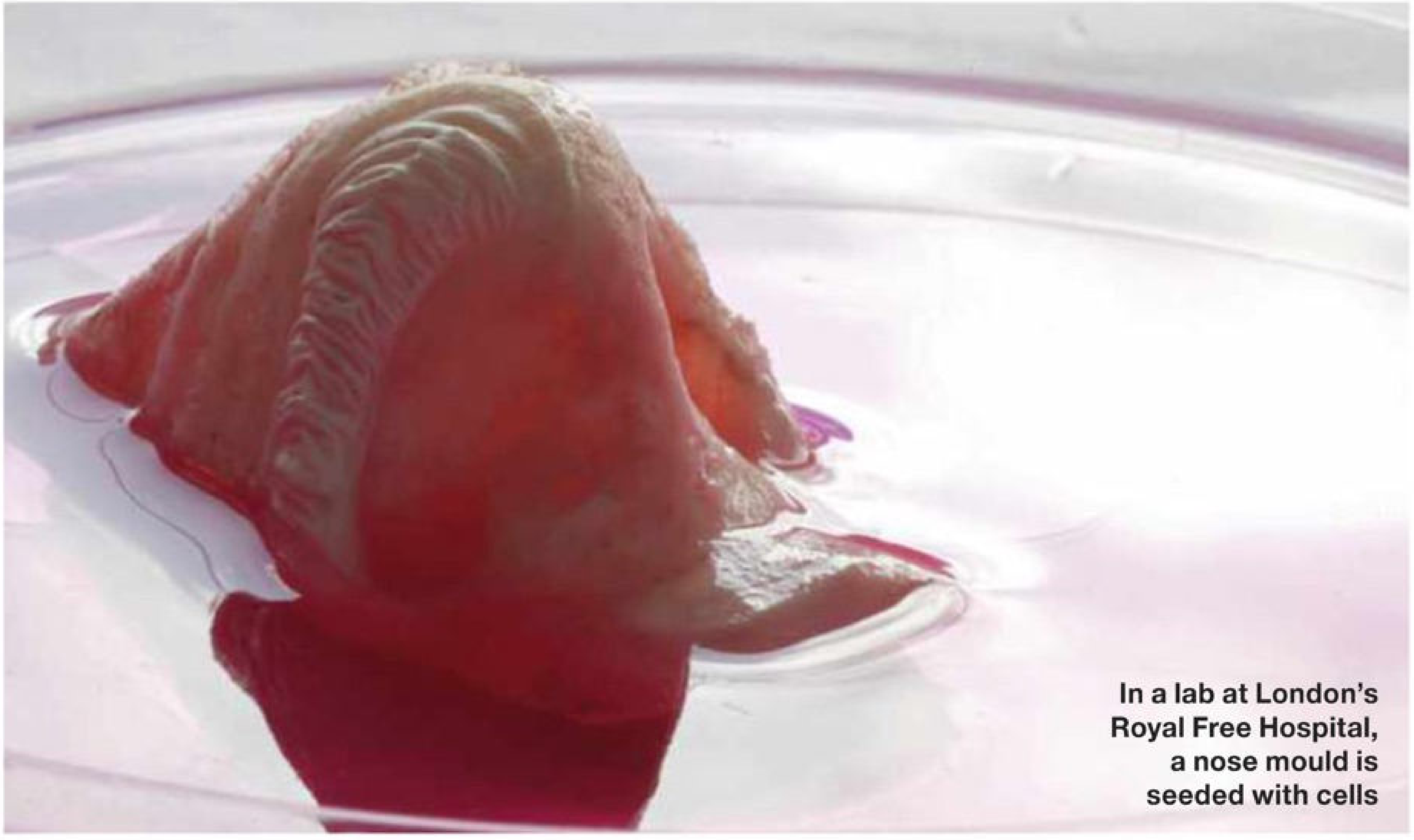
Replace or reprogram?

Up until now, the emphasis has been on cell therapies. For the last decade, the buzz in regenerative medicine has all been about stem cells. These are biological blank-slates with the ability to develop into various types of cell (see 'What is a stem cell?', p67), although not all stem cells can generate any cell type. Embryonic stem cells have the most potential for variety – they're able to give rise to every tissue in the body – whereas adult cells, such as mesenchymal stem cells from the bone marrow, tend to have more limited potential.

> *"Stem cell therapy makes a lot of sense, but I don't know of any solid studies that show it works"*

Through stem cell therapy, doctors could repair organs by using stem cells to generate more of a particular type of tissue as needed, grown either in the lab or inside an organ following a transplant. If those stem cells are derived from the patient, the need for donor organs is eliminated and the risk of rejection is minimised.

"Stem cell therapy makes a lot of sense and would be very valuable," says Professor David Sachs, director of the Transplantation Biology Research Center at Massachusetts General Hospital, Boston. "But I don't know of any solid studies that show it works." ▶



In a lab at London's Royal Free Hospital, a nose mould is seeded with cells

TIMELINE

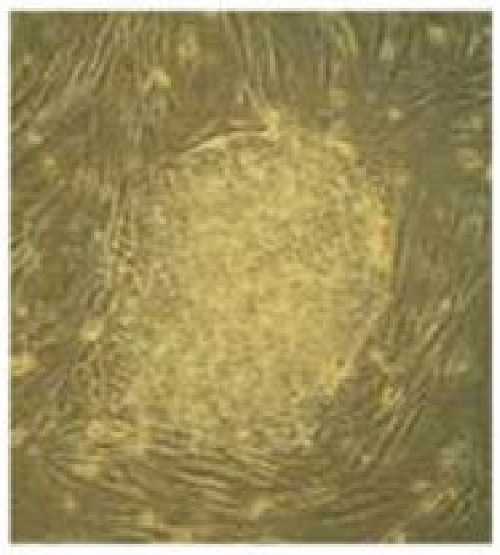
Advances in stem cell research have revolutionised regenerative medicine and enabled the repair and replacement of damaged tissues

Dolly the sheep and her first lamb

1996

CELLS ARE CLONED FROM AN ADULT MAMMAL

Biologists replace the DNA in an unfertilised egg with that from an adult mammary gland cell. The resulting embryo was carried in a surrogate mother, and Dolly the sheep was born. This showed that cloning embryonic stem cells from adult specialised human cells should, in theory, be possible.



A colony of human embryonic stem cells

1998

HUMAN EMBRYONIC STEM CELLS ARE CREATED

Cloned cells are identical to a patient's own body cells, preventing tissue rejection. The creation of a source of such cells came a step closer when a team at the University of Wisconsin, USA cloned embryonic cells derived from embryos donated following *in vitro* fertilisation.

SEAMUS MURPHY, SCIENCE PHOTO LIBRARY, CHRIS GOODFELLOW/GLADSTONE INSTITUTES, PRESS ASSOCIATION

WHAT IS A STEM CELL?

The key characteristic of stem cells is their ability to generate a variety of different types of specialised cells with specific functions in the human body, which includes everything from sperm and blood cells to nerve and muscle cells. Stem cells can create copies of themselves through division to renew their supply indefinitely. For research, cells can come from several sources.

EMBRYONIC STEM CELLS

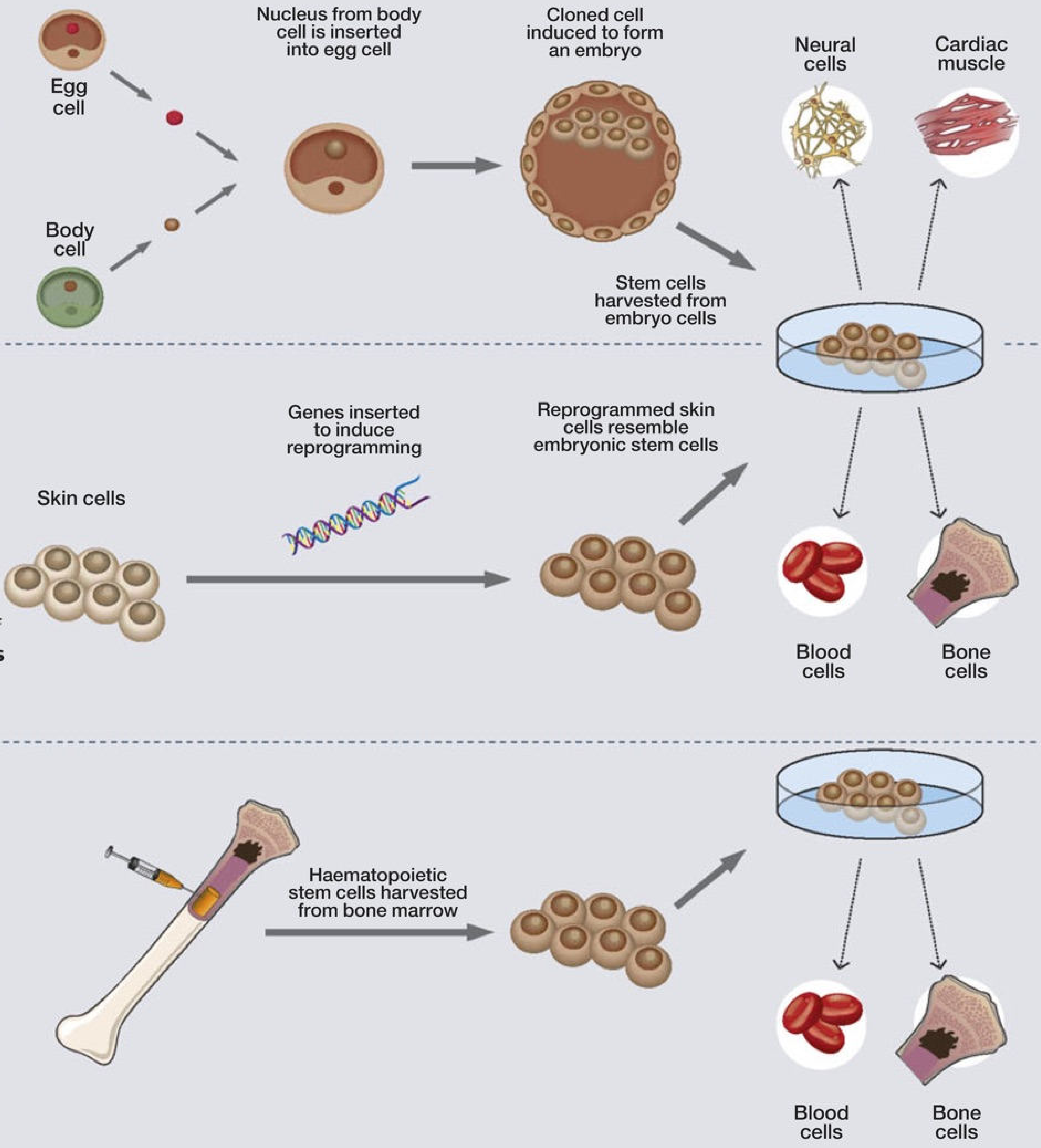
After five days, a fertilised human embryo is a hollow sphere of cells with a cluster of other cells inside. The sphere will form the placenta and amniotic sac while the cluster – called the inner cell mass – will ultimately become the body. When scientists grow the inner cluster in a culture dish, they're known as embryonic stem cells, which can in theory be made into any type of tissue.

INDUCED PLURIPOTENT STEM CELLS

Adding four specific proteins to adult cells can reprogram (induce) them into a stem cell-like state, a technique first shown to work in mice. These 'induced pluripotent stem cells' share the behaviour and characteristics of embryonic stem cells, including the ability to give rise to every cell type of the adult mouse. This approach avoids the ethical problems associated with using embryonic stem cells.

ADULT STEM CELLS

In an adult body, a small proportion of cells remain more 'embryonic' in nature, retaining a greater potential to become a variety of cell types. But many adult stem cells are difficult to isolate from their native tissues. Bone marrow is one of the more accessible sources and contains haematopoietic stem cells – which give rise to every type of blood cell – and mesenchymal stem cells, which can generate bone, cartilage, fat and connective tissues.

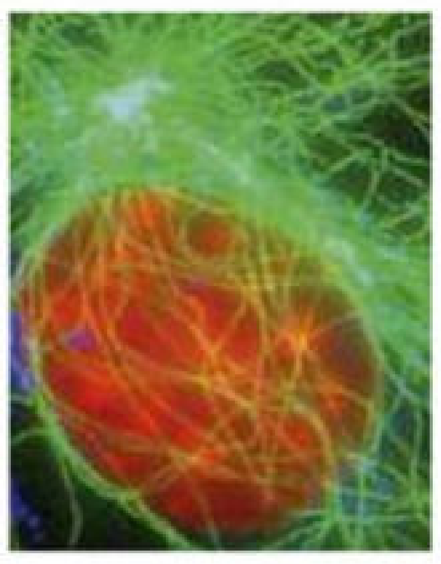

Egg cell
Body cell
Nucleus from body cell is inserted into egg cell
Cloned cell induced to form an embryo
Neural cells
Cardiac muscle
Stem cells harvested from embryo cells
Skin cells
Genes inserted to induce reprogramming
Reprogrammed skin cells resemble embryonic stem cells
Blood cells
Bone cells
Haematopoietic stem cells harvested from bone marrow
Blood cells
Bone cells

Shinya Yamanaka of Kyoto University

2006

STEM CELLS DERIVED FROM SPECIALISED CELLS

Human cloning and the creation of embryonic stem cells are technically and ethically difficult. A team at Kyoto University showed these hurdles could be overcome by converting adult mouse fibroblast cells into embryo-like stem cells by adding four proteins.



Fibroblast cells can be transformed

2010

SPECIALISED CELLS TRANSFORMED

Stem cells can multiply indefinitely, presenting a cancer risk, so a safer approach is to transform one type of cell into another type – transdifferentiation. In 2010, researchers converted fibroblast cells into other types – neurones, heart muscle and blood cells.

Molecular biologist Eric Olsen

2012

CELLS TRANSFORMED INSIDE A PATIENT

Two teams, led by Deepak Srivastava and molecular biologist Eric Olsen, have managed to change cells inside a damaged organ. In living mice, they converted scar tissue after a heart attack into heart muscle cells. The mice then showed improved heart function.

▸ Deepak Srivastava, of the Gladstone Institute of Cardiovascular Disease in San Francisco, adds that trials of stem cell therapies for people with heart damage haven't been as successful as hoped, and any improvements haven't been because stem cells gave rise to new heart cells. "The trials were started with that in mind but none of them have been even suggested to turn into new muscle," he says.

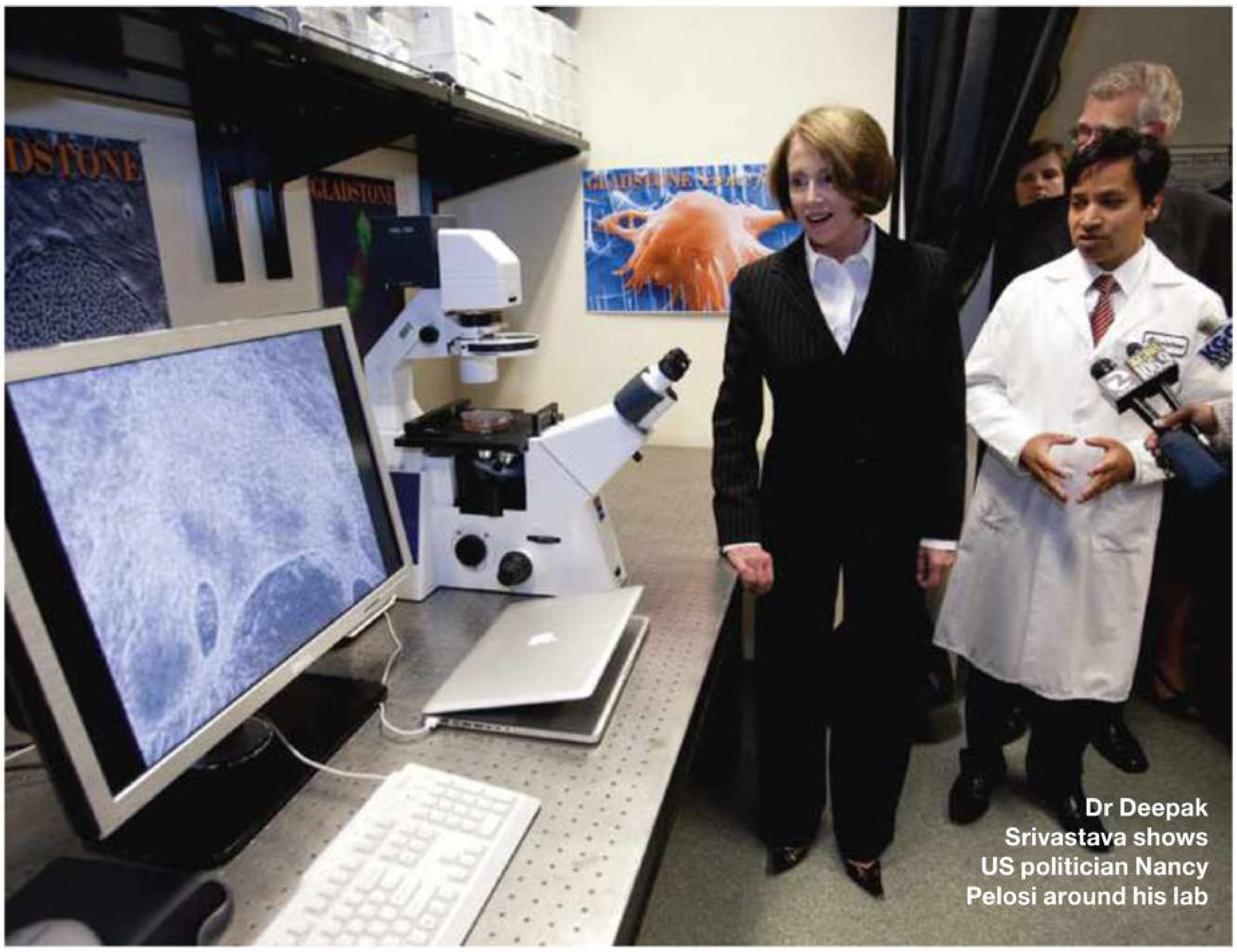
Instead, it's believed the stem cells release chemical growth factors that stimulate a heart to repair itself. The same sort of indirect effect may also be behind improvements seen in patients with kidney disease who've received stem cell transplants. But Srivastava doesn't believe this indirect effect is strong enough to offer significant heart repair, saying: "In order to get improved function, you have to create new muscle."

As well as improving existing stem cell transplantation techniques, Srivastava's lab is trying another approach to generating new heart muscle: directly reprogramming the cells that form scars – fibroblasts – into muscle cells, transforming one type of cell into a different type. This process, known as 'transdifferentiation', is currently being tested in mouse hearts.

The process works in much the same way as generating induced pluripotent stem cells. A combination of proteins is added to the fibroblast cells, and these proteins switch on genes that are normally activated in heart cells, changing their identity. The benefits are two-fold: as well as generating new muscle cells, the process also gets rid of scar tissue, which itself impairs heart function.

A similar technique has been used in mice to convert one type of cell in the pancreas into another type, the beta-cells that are specialised to produce insulin. If this approach works in humans, it could be used to treat people whose beta-cells have been destroyed due to type 1 diabetes.

Transdifferentiation has the potential to transform regenerative medicine, but research is still at an early stage. Indeed, the stem cell story is far from over: just when it seemed they might not live up to the early hype, some promising results with human embryonic stem cells have come into view – literally, through the transplant of retina cells to improve eyesight (see 'State of the part', p69).


Dr Deepak Srivastava shows US politician Nancy Pelosi around his lab

Although stem cells have the potential to give rise to various tissues, transplantation expert David Sachs suggests that stem cell therapies might be better suited to treating some tissues more than others. What's more, even working at their best, stem cells would only patch up damaged tissues, and sometimes that isn't enough.

"We've got two noses growing, just in case someone drops one"

Prof Alex Seifalian shows off the world's first synthetic trachea

So to meet the demand for entire replacement organs, tissue engineers are now building them from scratch.

Organs made to order

To start building an organ, you need a scaffold to guide the growth of a patient's cells. Anthony Atala makes his scaffolds from collagen – the main component of connective tissue – and synthetic polymers, or a mixture of the two. "It depends on the type of tissue and organ you are trying to regenerate," he explains. Luke's bladder, for example, had to stretch – it needed to have both structural integrity and elasticity, so a combination scaffold works best.

At University College London, Professor Alex Seifalian uses a similar scaffold technique to build tear ducts, arteries and, last year, the first artificial trachea (windpipe). The patient's own bone marrow cells were grown on the trachea, helping to prevent tissue rejection.

Seifalian's latest project is for a 53-year-old English man who has lost his nose to cancer (see 'How to grow a nose', p70). The man's bone marrow cells are currently growing in the lab on two nose-shaped scaffolds. "We've got two noses growing, just in case someone drops one," says Seifalian. ▸

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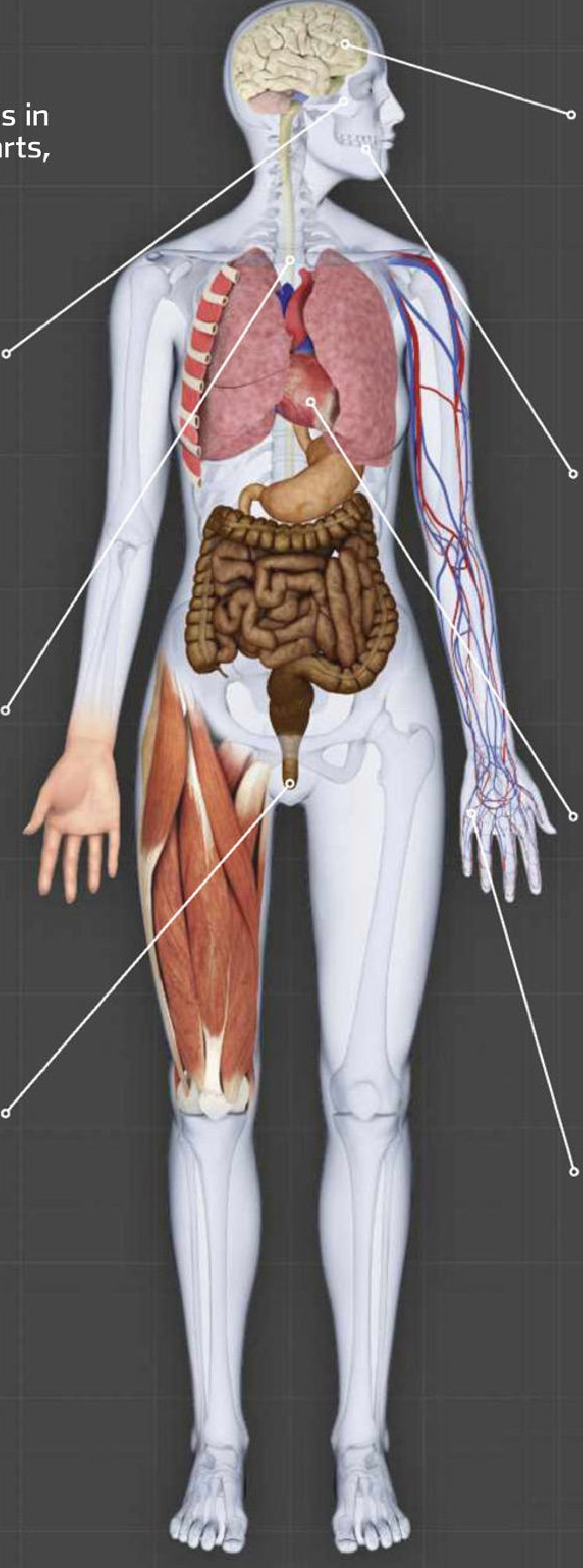
STATE OF THE PART

The latest breakthroughs in growing human body parts, from brains to bums



EYES

Advanced Cell Technology in Marlborough, Massachusetts is running a clinical trial that is treating patients suffering from vision loss caused by macular degeneration. The company is using retina cells derived from human embryonic stem cells. Thanks to this treatment, one patient has gone from being able to detect only hand movements to being able to count fingers and read a few letters on an eye chart.

WINDPIPE

Last summer, 36-year-old Andemariam Beyene became the first recipient of a biosynthetic trachea (windpipe). Beyene's own windpipe had been engulfed by a large tumour, and he could barely breathe. Tissue engineers, led by Alex Seifalian of University College London, extracted bone marrow cells and grew them on an artificial polymer windpipe before the new organ was surgically implanted. He celebrated its one-year anniversary in June.

ANAL SPHINCTER

At Anthony Atala's lab at the Wake Forest Institute for Regenerative Medicine in North Carolina, human muscle cells derived from a sphincter biopsy have been grown in circular bundles together with nerve cells from mice. These bioengineered sphincters have been transplanted into mice, where they developed a blood supply and could relax and contract like the real thing.

BRAIN

Scientists hope to replace brain cells destroyed by neurological disorders such as Parkinson's and Alzheimer's with new tissue derived from stem cells. In rats, Rudolf Jaenisch of the Whitehead Institute for Biomedical Research in Cambridge, Massachusetts has shown that the symptoms of Parkinson's disease were improved when neurones made from induced pluripotent stem cells were integrated into the brain.

TEETH

Biologists in Japan led by organ regeneration researcher Takashi Tsuji at the Tokyo University of Science have successfully grown a functional replacement tooth in an adult mouse. They transplanted a bioengineered tooth-bud containing foetal tooth-bud cells into the socket of a missing tooth and, about a month later, a new gnasher emerged.

HEART

Several research teams, including one led by Deepak Srivastava of the Gladstone Institute for Cardiovascular Disease in San Francisco, are currently trying to directly reprogram fibroblast cells – which form scar tissue after a heart attack – into functioning heart muscle cells. In mice, this approach has significantly reduced scar tissue formation and increased the amount of blood that their hearts could pump.

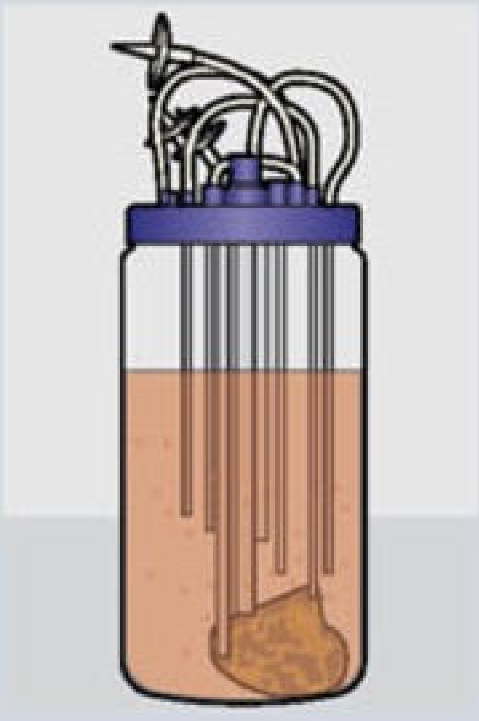
VEINS

Doctors in Sweden, led by regenerative medicine researcher Suchitra Sumitran-Holgersson of Sahlgrenska Science Park, have transplanted a bioengineered portal vein (which runs from the stomach to the liver) into a 10-year-old girl whose own vein was obstructed. A donor vein was stripped of its cells and repopulated with cells grown from the girl's bone marrow – to prevent tissue rejection – before being transplanted.

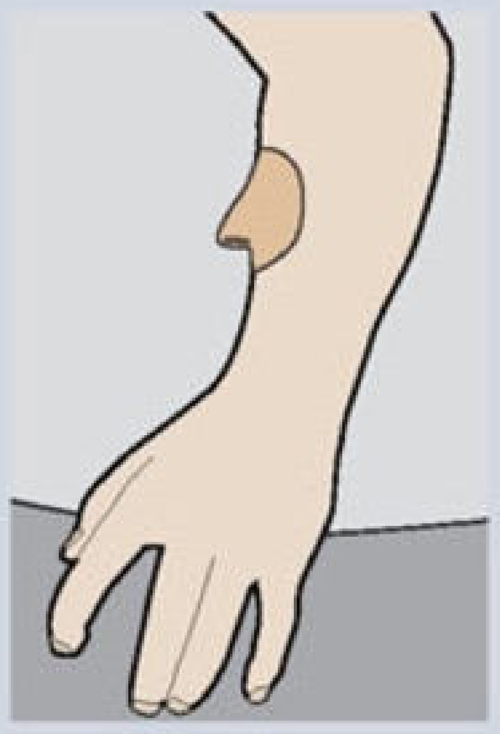
HOW TO GROW A NOSE

Your step-by-step guide to producing a prosthetic proboscis

1 A mould of the patient's original nose is taken prior to its surgical removal. This mould is used to create a second mould – made of glass – into which a polymer scaffold is sprayed. Cells from the patient's bone marrow are grown in the lab and then added to the nose scaffold, which is placed in a bioreactor – a large jar-like container that rotates.



2 For about two weeks, the bioreactor is maintained at body temperature (37°C), which helps the cells to grow all over the scaffold. At the same time, a small balloon is placed under the skin on one of the patient's arms. Every few days this balloon is inflated a little more to encourage the skin to stretch.



3 The scaffold, covered in the patient's cells, is removed from the bioreactor and surgically implanted under the stretched skin on the patient's arm, where it will remain for four to six weeks as it develops a blood supply. The nose, together with its new skin, is then extracted from the arm and surgically attached to the patient's face.

4 Attaching the nose is a complex, delicate procedure because many tiny blood vessels need to be reconnected. If this operation is deemed a success, the surgical team will later remove the skin covering the nostrils. Mucous membrane cells derived from the patient will then be implanted into the nostril cavities, producing a functional organ.

▶ The process involves implanting one of the noses under the skin on the patient's arm. "We can make the nose, but we can't make the skin," Seifalian explains. Then, four to six weeks later, the nose will be transferred – together with its skin covering – to the patient's face. Initially, the new nose won't have working nostrils because they'll be covered with skin. But once doctors are happy with the nose in place, they plan to open the nostrils and introduce epithelial cells, which form the mucus membranes that protect body surfaces.

Making noses, windpipes and bladders to order certainly seems impressive, but both Seifalian and Atala say that these hollow organs are relatively simple to create, compared to making a solid organ such as a liver, kidney or pancreas. One approach to tackling trickier tissues such as these is to pump mild detergent through the blood vessels of an existing organ until all its cells have been washed away, then add new cells onto the remaining connective tissue. And because cells are required to invoke an immune response, the remaining structure from, say, a pig's heart or a human donor could be used to grow a patient's heart cells without fear that the new organ would be rejected.

Last year, Atala used this approach to make a miniature liver seeded with cells from the liver and the lining of the blood vessels of a foetus. This produced an organ that acted like a basic liver. "We looked at various liver functions, including drug metabolism, and showed that our mini-livers could do them," says Atala, who is now trying to transplant these mini-livers into rodents.

Just hit Ctrl+P

Atala is also trying another approach to making organs: printing. The technique works a lot like a computer printer except that, instead of having cartridges containing different inks, the printer contains cells and the components of a scaffold. A computer then directs the cartridges to print out, say, a kidney – layer by layer.

But recreating the complex functioning of an organ might not be as straightforward as merely printing. For example, the glomeruli – the filter units the kidney uses to clean blood – consist of about 25 different types of cell. These cells not only have to be present, they also have to be in the right place relative to their

An artificial bladder being seeded with the recipient's own cells

GETTY, PRESS ASSOCIATION, ILLUSTRATIONS BY PAUL WOOTTON

Dr Deepak Srivastava tests a skin sample from a patient with a genetic heart complaint

neighbours. Like factory workers on a production line, each has a specific position and job to do. When an embryo develops, chemical signals help direct where and when the various cells should appear.

It's unclear how those chemical directions will work in an isolated organ, however, and there are other big hurdles to overcome, such as how to incorporate and maintain a blood supply. Consequently, Atala predicts it could be decades before a person can have an organ printed to order.

Out on a limb

And if that's not 'sci-fi' enough for you, how about growing back organs we've lost? Although this might seem far-fetched, some scientists believe it's a real possibility.

Cut off a child's fingertip and chances are it will grow back – skin, muscle and bone, all as good as the original. This even works in some adults. But please don't try it at home: for one thing, if the fingertip does grow back, it might take three months or more. You also have to be quite precise – cut too close to the first joint and no regrowth will occur.

But our capacity for natural regeneration still falls far short of the abilities seen in certain fish and amphibians. Take the salamander: should it lose its tail or a limb, it simply grows a new one. Even internal organs can regenerate when damaged. So could regenerative medicine give humans the power to regrow an entire limb? The rationale is that if animals as simple as amphibians are able to regrow limbs, then our own, very distant ancestors might have once possessed similar powers.

Like any other characteristic, regeneration is under the pressure of natural selection. And for whatever reason, over the course of evolution, perhaps our distant ancestors largely lost this power. But while the genes and biological pathways responsible may not have been used for several hundred million years, it might be possible to work with the remaining pathways to reactivate our long-lost regenerative abilities.

Professor Ken Muneoka is one of the scientists who believes regeneration is possible. A tissue engineer at Tulane University in New Orleans, he's trying to stimulate the regeneration of digits in mice, and has discovered a cocktail of growth factors that can promote extension of digits under conditions that wouldn't normally trigger regeneration. But there is a limit. "You can get a regenerative response that brings you up to the knuckle region but no further," says Muneoka.

Regrowing a digit might not seem like the highest priority on the organ list, but it proves the concept is sound. "If we can regrow a finger then we'll be able to regrow a leg," says Muneoka, who is now shifting his research toward regenerating joints. He receives some funding from the US military for obvious reasons, because his work has clear applications for soldiers who lose appendages in combat, and Muneoka's cocktail of growth factors has already been shown to promote extension in the amputated legs of mice.

"If we can regrow a finger then we'll be able to regrow a leg"

There may be hope for regenerating internal organs, too. In February last year, molecular biologists at the University of Texas in Dallas reported that one-day-old mice could regenerate their hearts after portions had been surgically removed. Although the mice lost this ability after a week, the fact that the potential for salamander-style regeneration exists – albeit fleetingly – holds promise that the biological pathways involved could be reactivated in adulthood, a period when many of us are in need of heart repair.

"I've always thought the ultimate goal will be to regenerate tissues and organs in the same way that an amphibian does," says David Sachs. "But it is going to be a long time before we figure out all those pathways and can make them all work again. If we could be frozen and come back in a few hundred years, if someone loses an arm, they'll grow it back."

Based on what scientists have already achieved, it seems increasingly likely that we'll one day be able to grow parts to order – whether that's in our bodies or in the lab. Repairing and replacing organs through regenerative medicine might even become as routine as getting a filling at the dentist, changing the nature of healthcare as we know it. Which would be a lot more impressive than regrowing a fingertip. ■

Dr Ruth Williams is a science writer and former stem cell biologist

BBC RADIO 4 92–95FM & 198LW

For *Britain's Labs* on Radio 4, Prof Iain Stewart visited the Centre for Regenerative Medicine in Edinburgh to find out about stem cell research: www.bbc.co.uk/i/shrm2/

Q&A

Your questions answered

When will we start mining asteroids? p75
Can humans pass viruses to animals? p76
What's the fastest police car in the world? p78
Why do we rub our eyes when we're tired? p80

Charlie the parrot is 104 years old, and used to belong to Winston Churchill

Why do parrots live so long?

MICHAEL NIMAN, LONDON

Parrots are the longest-lived order of birds: cockatoos and Amazonian parrots can reach the age of 75 or older. Even budgerigars live for 15-25 years, which is an exceptionally long life for such small animals. The reason for this is that they have few predators and are often colonial, so their chances of finding food are better.

Species with lots of predators can't expect to escape being eaten for more than a few years. So they evolve to reproduce as quickly as possible, and in large numbers. This takes a lot of metabolic resources out of the adults, and they are more likely to die shortly after breeding. Even more importantly, genetic mutations that might cause disability or disease later in life don't have any effect on natural selection because those individuals have already reproduced. This means mutations of this sort tend to accumulate in the species, and so its maximum natural lifespan will tend to shorten.

In the absence of parrot predators, natural selection has weeded out most of these mutations from their gene pool. **LV**

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2.56 **terabits per second is the transmission rate achieved by researchers using 'twisted' beams of light to transfer data. That's 85,000 times faster than a typical 30Mbps broadband connection**

Send us your questions

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Why don't people living in the Arctic get scurvy?

ALAN BLACKWOOD, IPAD APP

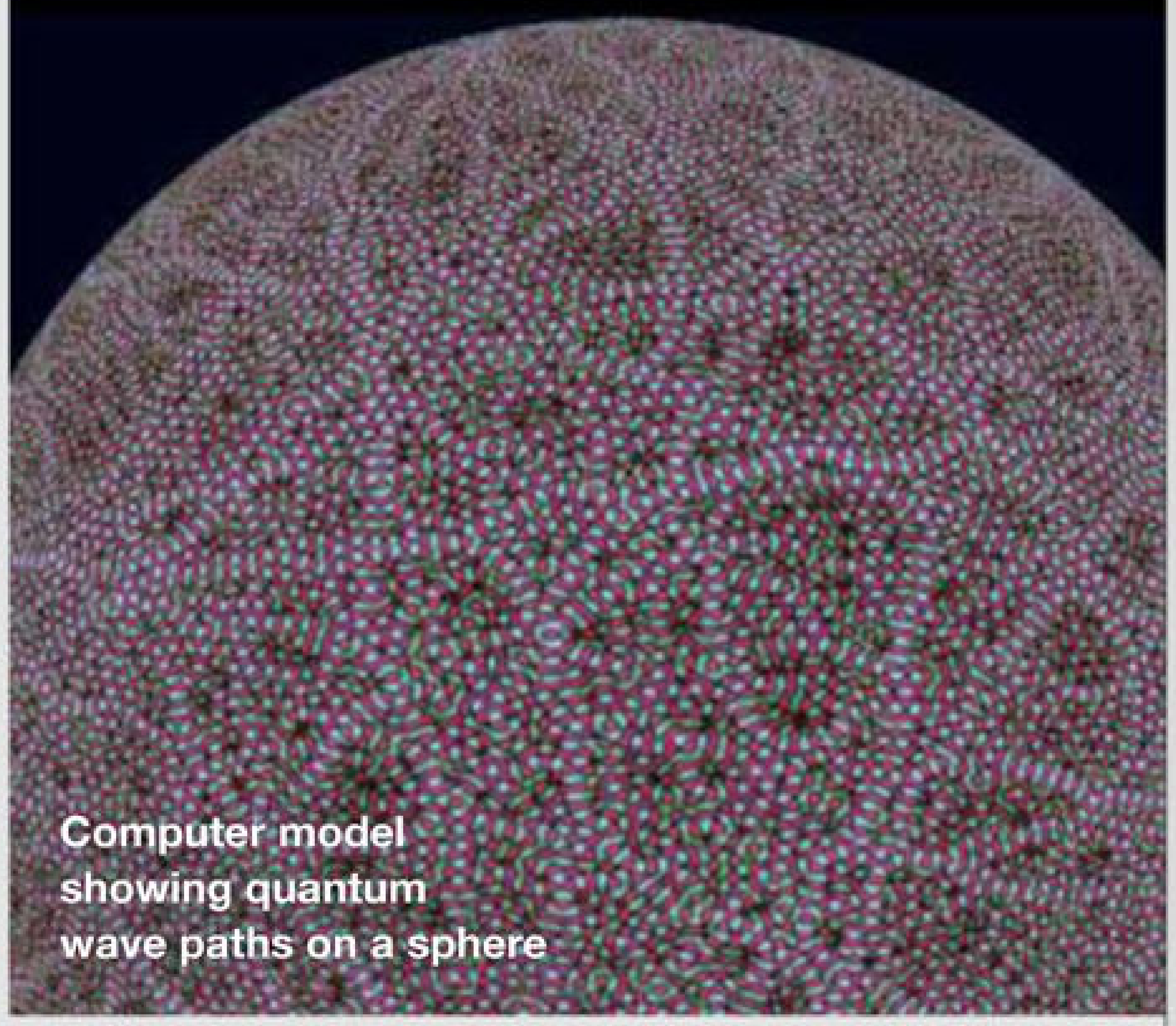
The traditional diet of the Inuit, Yupik and other Arctic peoples is very low in carbohydrate, and very high in protein and fat. But it does contain adequate vitamins. Caribou liver, seal brain and kelp all contain vitamin C. Whale skin contains 38mg of vitamin C per 100g, compared with 53mg for lemons and 29mg for limes. By eating the meat raw, its vitamin content is preserved. **LV**

Arctic people get vitamin C from raw whale meat

What is quantum superposition?

MATT LEVY, CUMBRIA

One of the strangest aspects of the sub-atomic world is that particles with several different possible states are able to exist in all of them simultaneously. For example, electrons can have their spin axes pointing up or down, but quantum theory says they can also exist in a 'superposition' of both up and down spins. This bizarre effect could be exploited by future quantum computers, as it allows particles to perform more than one role at a time, leading to a huge increase in computing speed. **RM**



Computer model showing quantum wave paths on a sphere

IBM's Blue Gene supercomputer. Future models will be more powerful but probably not conscious

How powerful would a computer have to be to match human consciousness?

ANDREW CIREL, IPAD APP

Philosophers and scientists have proposed many tests for machine consciousness. One is being able to perceive voices – but the iPhone personal assistant Siri uses voice recognition, and nobody would argue *that* is conscious. A machine passes the Turing Test if a user is unable to distinguish between interacting with it and a human. But even that is some way from saying the computer has self-awareness or emotions. Views vary, but mine is that no amount of computation is sufficient for 'strong' artificial consciousness, whereby a machine has feelings, is self-aware and is capable of abstract reasoning. But if an appearance of sentience is sufficient, all it takes is one of the many chatbots available online. **GM**

The **experts**

SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN
Alastair is a radio astronomer at Jodrell Bank Centre for Astrophysics

ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service

LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach the Ground*

QUESTION OF THE MONTH

How many trees are needed to provide enough oxygen for one person?

AARON HACON, NORWICH

Aaron wins a copy of Nature's Weirdest Events on DVD (BBC, £16.33)

A full-grown tree produces around 100kg of oxygen per year

Trees release oxygen when they use energy from sunlight to make glucose from carbon dioxide and water. Like all plants, trees also use oxygen when they split glucose back down to release energy to power their metabolisms. Averaged over a 24-hour period, they produce more oxygen than they use up; otherwise there would be no net gain in growth.

It takes six molecules of CO_2 to produce one molecule of glucose by photosynthesis, and six molecules of oxygen are released as a by-product. A glucose molecule contains six carbon atoms, so that's a net gain of one molecule of oxygen for every atom of carbon added to the tree. A mature sycamore tree might be around 12m tall and weigh two tonnes, including the roots and leaves. If it grows by five per cent each year, it will produce around 100kg of wood, of which 38kg will be carbon. Allowing for the relative molecular weights of oxygen and carbon, this equates to 100kg of oxygen per tree per year.

A human breathes about 9.5 tonnes of air in a year, but oxygen only makes up about 23 percent of that air, by mass, and we only extract a little over a third of the oxygen from each breath. That works out to a total of about 740kg of oxygen per year. Which is, very roughly, seven or eight trees' worth. **LV**

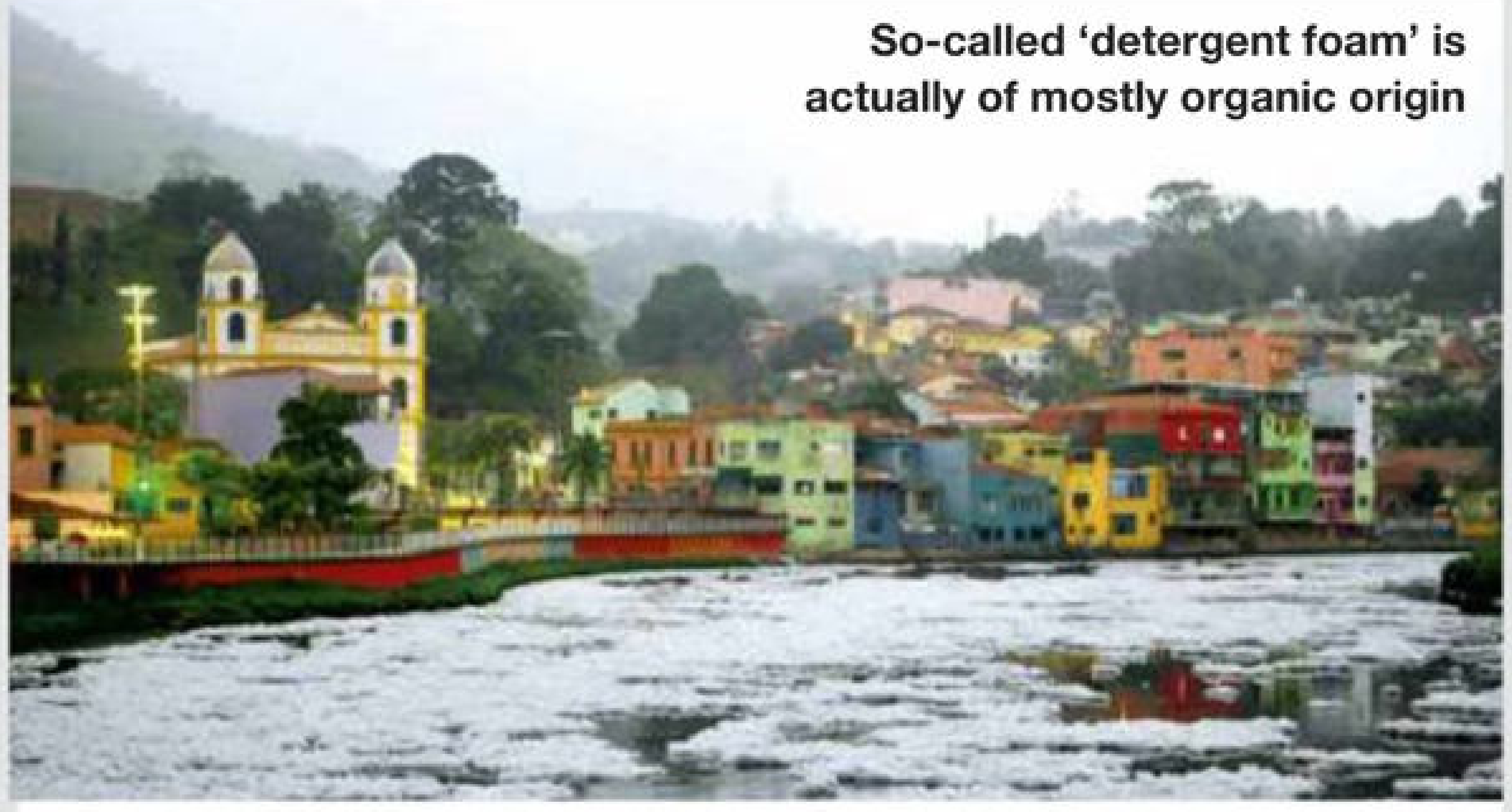
Chaser the border collie is said to understand over 1,000 words

Do dogs have better memories than cats?

CLIVE BARBARA, IPAD APP

They have different kinds of memory, so it's hard to say which is better. Dogs are easier to train than cats, but this may be because they evolved to hunt in packs, cooperate with other dogs and be subservient to a leader. Their memory requires plenty of reinforcement, otherwise they quickly forget. But they can be rewarded, as can children, simply by giving them attention.

Cats evolved to hunt solo and are much more devious. They too can be trained but do not have the dog's desire to please, and they need direct rewards such as food. There is some evidence that cats remember specific events longer than dogs do, but both species have excellent memory for people and places, enabling them to build complex mental maps of their surroundings and to find their way home. **SB**



So-called 'detergent foam' is actually of mostly organic origin

How do household cleaning products affect the environment?

AMY RHYS-DAVIES, CAMBRIDGE

From detergents to bug-killing bleach, we use a lot of pretty nasty chemicals in the home, much of which can end up entering the environment via the drains. Yet the notorious 'detergent foam' seen in rivers and streams is usually the result of entirely natural bacterial action on decaying vegetation, whose cells break down to produce so-called surfactants that foam up easily. As for bleach, studies have shown that it rapidly breaks down in the environment, posing no serious hazard. **RM**

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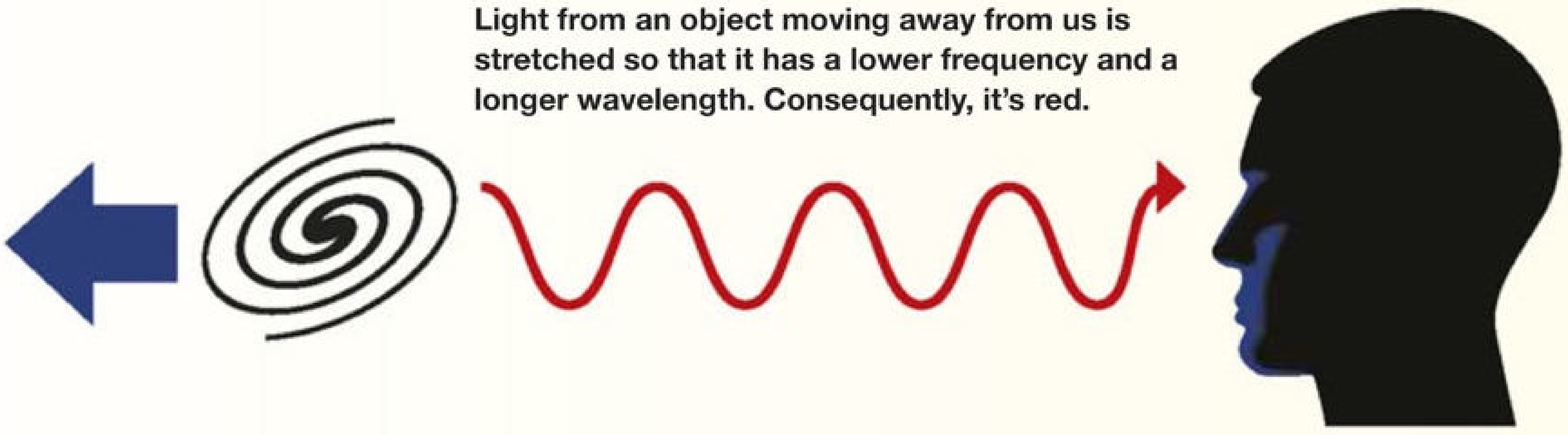
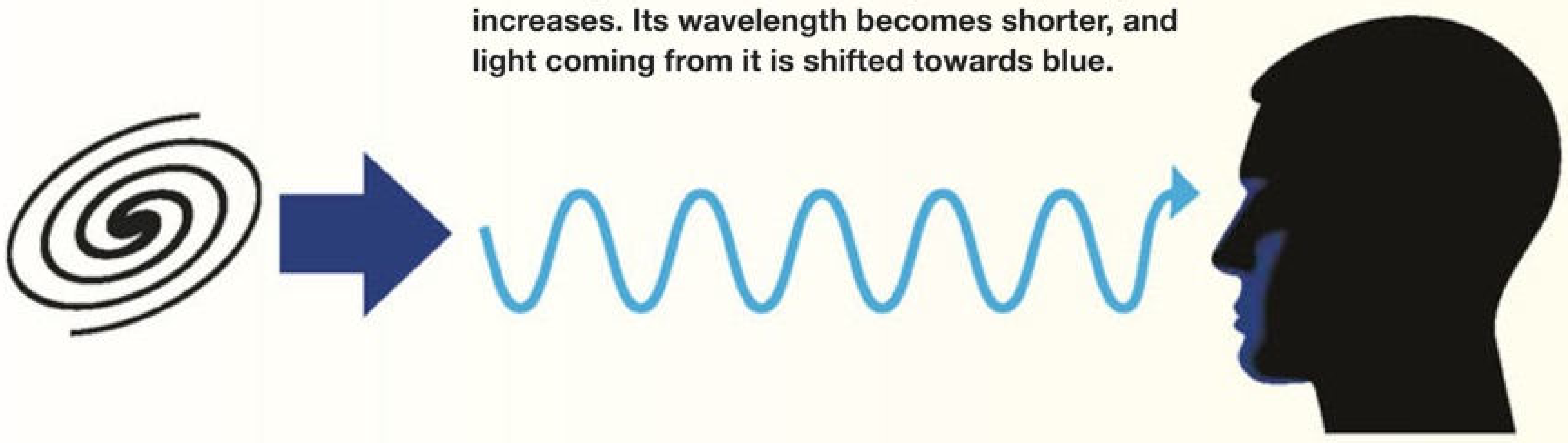


Light from an object moving away from us is stretched so that it has a lower frequency and a longer wavelength. Consequently, it's red.

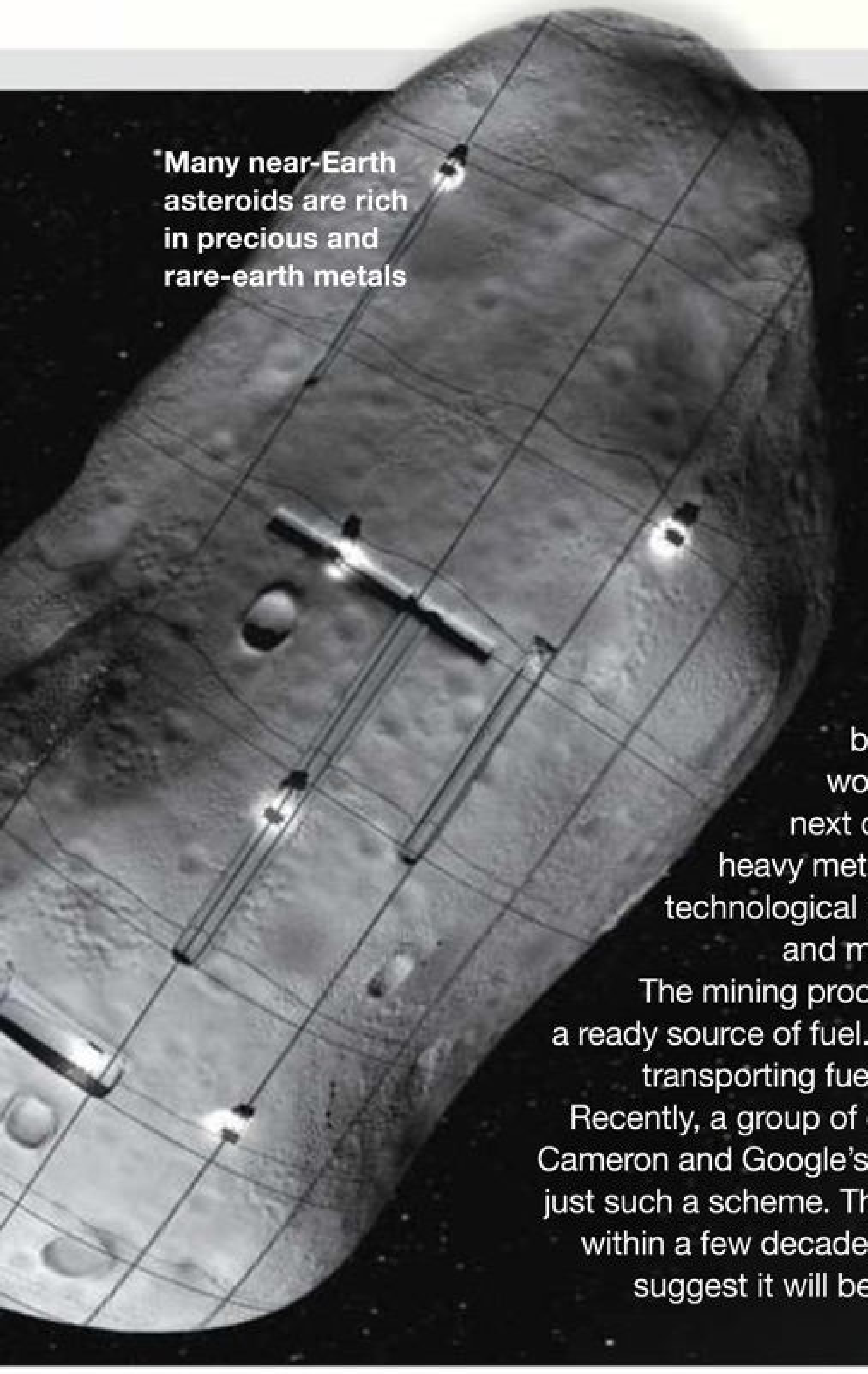


If the object moves toward us, the frequency increases. Its wavelength becomes shorter, and light coming from it is shifted towards blue.

What causes redshift in light?

JOHN CORFIELD, DEVON

Imagine I throw balls to you at a constant rate. If we both stand still, you receive balls at the same rate. But if you run away from me, each ball has further to travel, and so you will have to wait longer for each one. Instead of receiving one ball per second, you might only get one every 1.2 seconds; in other words, their frequency decreases. If we switch from balls to photons, the same thing applies. Photons that leave me at one frequency will appear (to you) to arrive at a lower frequency. The expansion of the Universe means *everything* is moving apart, and the further away it is, the faster it is moving relative to us. So light from distant sources appears to be shifted to a lower, redder frequency. **LV**



Many near-Earth asteroids are rich in precious and rare-earth metals

When will we start mining asteroids?

ANABEL BARKER, LONDON

The idea of harnessing the resources of asteroids has been around for some time. Such an endeavour would be extremely costly and technically very challenging, but would have undeniable benefits for humankind. Within the next century or so we may well exhaust the Earth's supply of heavy metals. These are essential in sustaining our economic and technological progress. Elements such as zinc, cobalt, gold, platinum and many others are actually relatively abundant in asteroids. The mining process could also extract hydrogen and oxygen, providing a ready source of fuel. This would alleviate many of the costs associated with transporting fuel from Earth, providing us with 'filling stations' in space. Recently, a group of entrepreneurs including film-maker and explorer James Cameron and Google's chief executive Larry Page announced plans to pursue just such a scheme. They estimate that commercial mining could be achieved within a few decades. But many scientists and engineers are sceptical, and suggest it will be 50 years or more before we start mining asteroids. **AG**

QUICKFIRE

How long does it take to completely shed your skin?

STEPHEN COLLINS, BY EMAIL

Your skin comprises 12-15 percent of your body weight but only the very top layer, the stratum corneum, is shed. This is just 10 to 30 cells thick. You shed about 1.5g of skin per day but the turnover is much faster on your palms than, say, your eyelids. Overall it takes 28 to 50 days to completely renew your skin, slowing as you grow older. **LV**

How would a spaceship navigate in deep space?

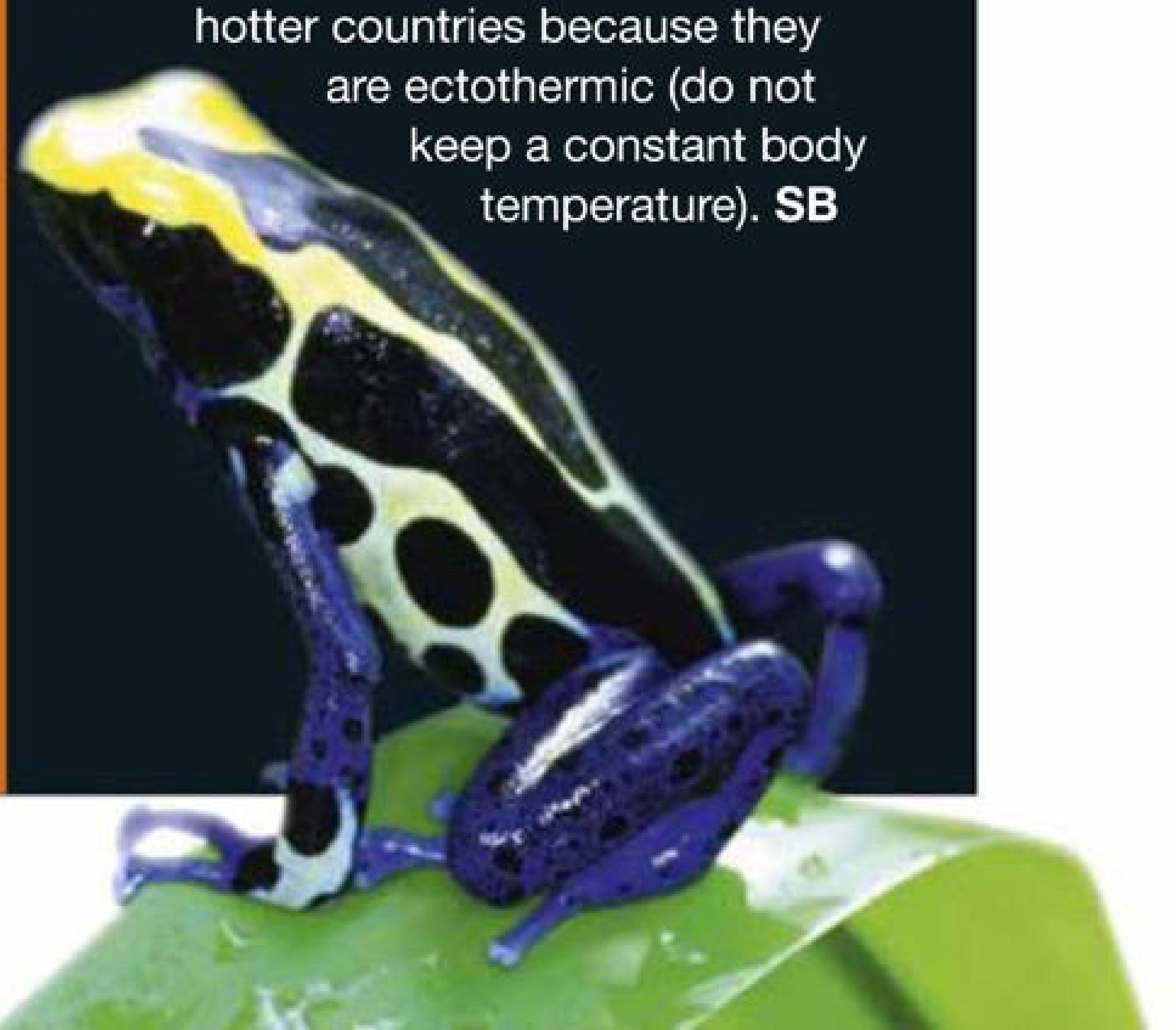
DUNK ANDREWS, AUCKLAND, NEW ZEALAND

Today, engineers track distant probes with Earth-based radio antennas, to determine their position and velocity at a given time. It is then easy enough to calculate the required corrections to the spacecraft's trajectory and send it the relevant commands. But this technique is limited to our immediate neighbourhood. If we ever send spacecraft further afield they will have to navigate autonomously. To do this they will almost certainly use detectors to locate objects of known position in the sky, such as pulsars, and take bearings from these objects. **AG**

Why do hotter countries have more poisonous plants and animals?

GREGOR LOMAX, DURHAM

In deserts, every drop of water is so precious that plants protect themselves with sharp spines, nasty tastes or poisons. However, there are poisonous plants in almost every climate. Poisonous animals are found widely except among birds, and the majority live in tropical and subtropical coastal seas. Many reptiles are poisonous and tend to live in hotter countries because they are ectothermic (do not keep a constant body temperature). **SB**



TOP TEN FASTEST LAND ANIMALS

1. Cheetah
113km/h (70mph)
They can accelerate from 0-60mph in just three seconds

2. Pronghorn antelope
98km/h (61mph)
They have a large heart and lungs that help them to go fast

3. Springbok
90km/h (56mph)
They can leap 4m into the air and long-jump up to 15m

4. Quarterhorse
88.5km/h (55mph)
They excel at sprinting short distances

5= Thomson's gazelle
80kmh/ (50mph)
They can outlast cheetahs in long chases and make speedier turns

5= Wildebeest
80km/h (50mph)
They defend themselves from predators by running as a herd

5= Lion
80km/h (50mph)
They combine stealth with bursts of speed when hunting

8= Elk
72km/h (45mph)
They can outrun their main predators – coyotes, wolves and dogs

8= Cape hunting dog
72km/h (45mph)
They are endurance runners, achieving 48km/h (30mph) over 4.8km (3 miles)

10. Coyote
69km/h (43mph)
They use their speed to hunt rabbits, mice, squirrels and livestock

How do we think?

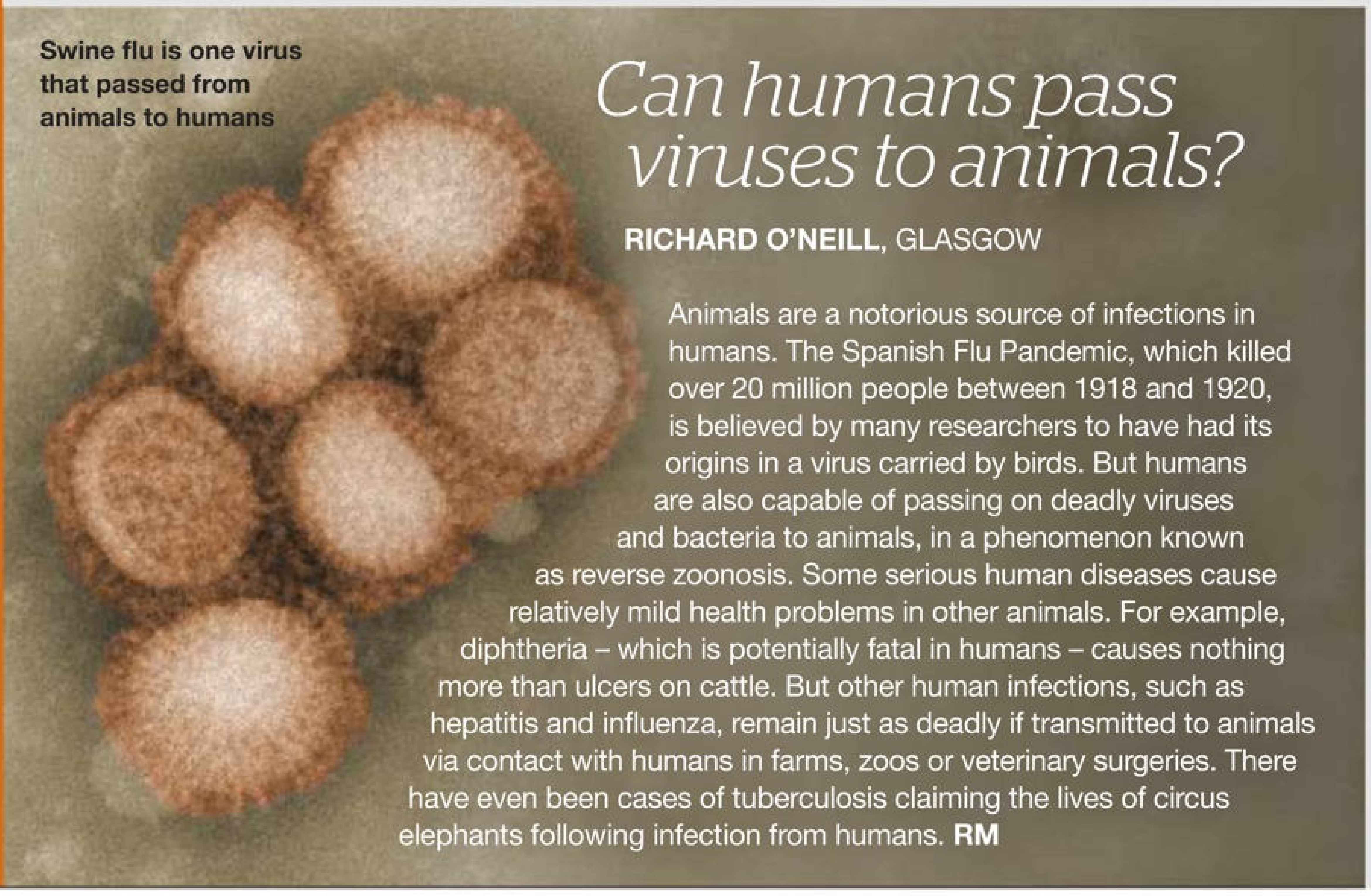
LILY STRINGER, ST ANDREWS

What an impossible question! If I could answer it I would have solved a great philosophical puzzle – how activity in a brain can be 'about' something, such as wanting a strawberry ice cream or solving an equation. This is known as the problem of 'intentionality'.

We do know which brain areas are involved in thinking. For example, parts of the visual cortex at the back of your brain use more energy when you imagine seeing the ice cream, and parts of the sensory cortex when you think about its feel and taste. When you are doing mental arithmetic a different set of brain regions is involved, including areas in the parietal lobe, prefrontal cortex and cingulate, deep inside the brain. Although maths is popularly supposed to be a left-brain skill, both hemispheres are involved, with the left hemisphere more important when thinking about numbers as words.

These examples show that we can correlate brain activity with thinking, but we are a long way from fully answering your question. **SB**

Brain activity can be mapped, but the process of 'thinking' is still not fully understood



Swine flu is one virus that passed from animals to humans

Can humans pass viruses to animals?

RICHARD O'NEILL, GLASGOW

Animals are a notorious source of infections in humans. The Spanish Flu Pandemic, which killed over 20 million people between 1918 and 1920, is believed by many researchers to have had its origins in a virus carried by birds. But humans are also capable of passing on deadly viruses and bacteria to animals, in a phenomenon known as reverse zoonosis. Some serious human diseases cause relatively mild health problems in other animals. For example, diphtheria – which is potentially fatal in humans – causes nothing more than ulcers on cattle. But other human infections, such as hepatitis and influenza, remain just as deadly if transmitted to animals via contact with humans in farms, zoos or veterinary surgeries. There have even been cases of tuberculosis claiming the lives of circus elephants following infection from humans. **RM**

GETTY, C.S. GOLDSMITH AND A. BALISH, ALAMY, THINKSTOCK X2

Does 'double or nothing' betting really work?

LARRY ALBION, OXFORD

Sometimes known as Martingale betting, the idea of doubling up each time you lose seems to make sense, because when you do win, you'll cover all those lost bets as well. And it can work – up to a point. For example, in Las Vegas the roulette wheel offers 'evens' odds on red/black and odd/even, while the true probability of winning is just slightly lower than evens, at 47.5 per cent. So if you have $100, you could play double-or-quits six times before running out of money, the first bet costing $1, then next $2, then $4, and so on, up to $32. Probability theory shows that the chances of you losing all six of these bets is around 1 in 50, so there's a good chance you'd come out ahead.

So why don't people use it all the time? The reason is that there's no telling how long a losing streak will last, and it could last longer than your ability to keep doubling up. Casinos are also wise to Martingale betting, and impose strict house limits on the maximum bets that can be placed. In the end, all betting systems run into the same problem: none can turn a game where the odds are stacked against you into a long-term source of profit. **RM**

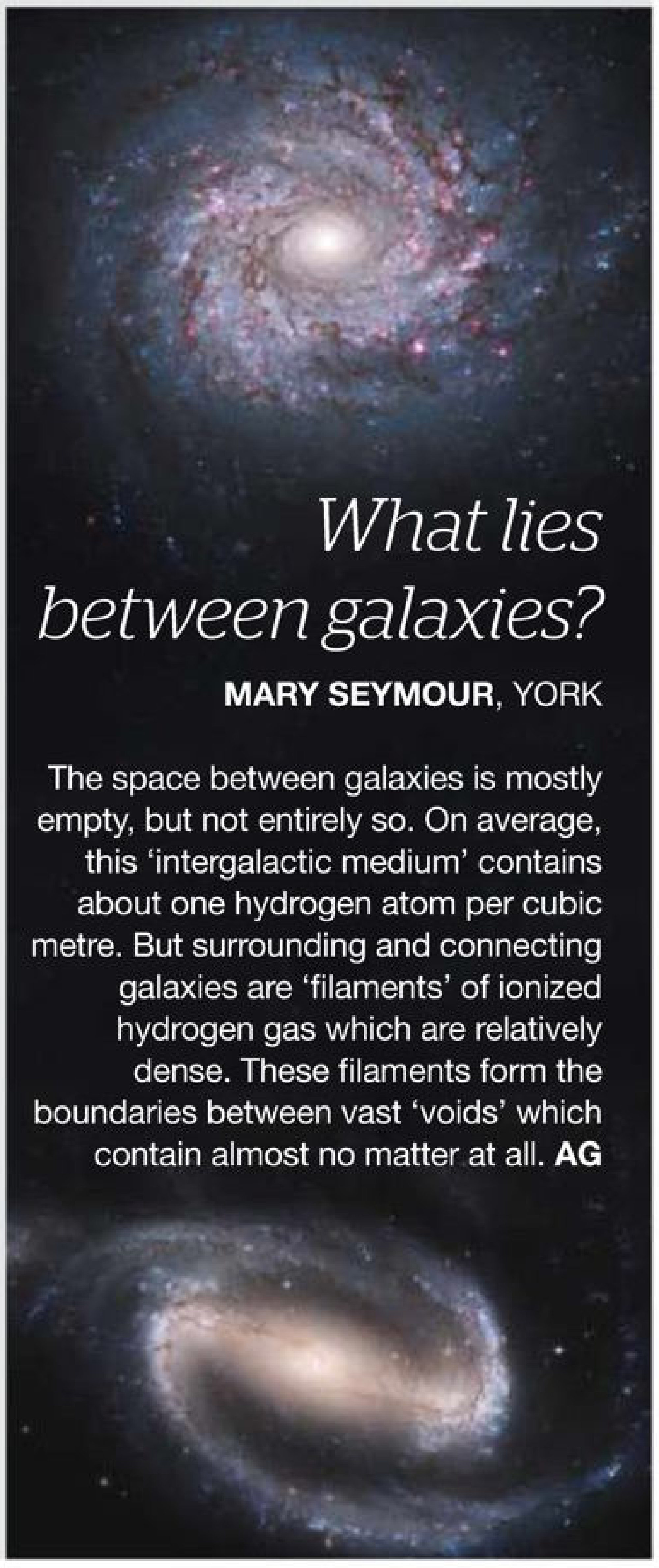
Casinos' house limits prevent Martingale betting from being an effective strategy

Why do birds jerk their heads when walking?

JOHN HOLLIER, CANTERBURY

A pigeon on a treadmill won't bob its head

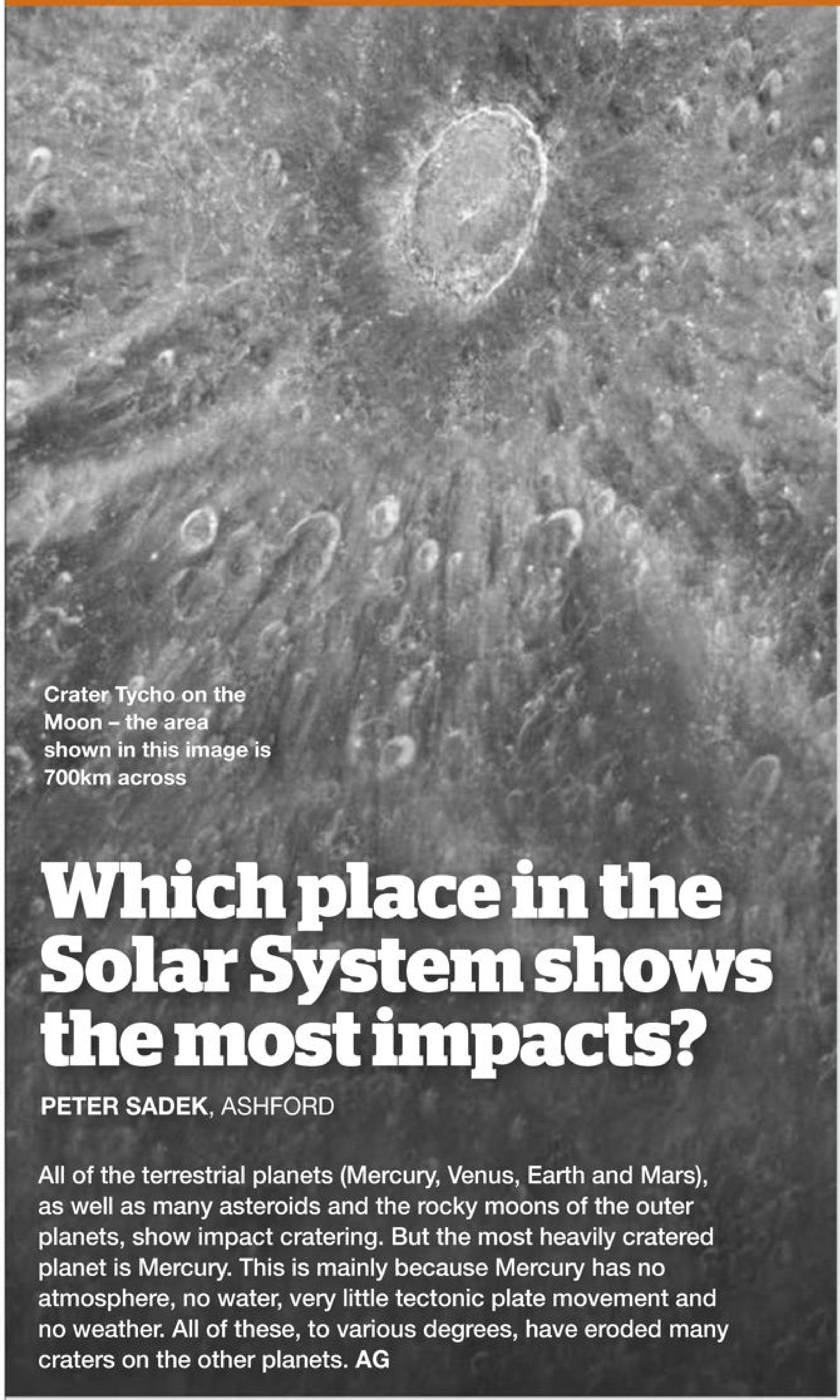
Like a pirouetting dancer twisting her neck to remain looking forwards for as long as possible, the bird's head moves backwards relative to the body in order hold it steady relative to the ground. At the end of each step the head jerks forward again, ready for the next step. This gives the bird intermittently clear and blurry vision, which is more useful than vision that is constantly slightly blurred. Head bobbing is driven by vision, not movement – pigeons on treadmills don't bob their heads because their surroundings aren't moving, but if you carry them they will still bob. **LV**



What lies between galaxies?

MARY SEYMOUR, YORK

The space between galaxies is mostly empty, but not entirely so. On average, this 'intergalactic medium' contains about one hydrogen atom per cubic metre. But surrounding and connecting galaxies are 'filaments' of ionized hydrogen gas which are relatively dense. These filaments form the boundaries between vast 'voids' which contain almost no matter at all. **AG**



Crater Tycho on the Moon – the area shown in this image is 700km across

Which place in the Solar System shows the most impacts?

PETER SADEK, ASHFORD

All of the terrestrial planets (Mercury, Venus, Earth and Mars), as well as many asteroids and the rocky moons of the outer planets, show impact cratering. But the most heavily cratered planet is Mercury. This is mainly because Mercury has no atmosphere, no water, very little tectonic plate movement and no weather. All of these, to various degrees, have eroded many craters on the other planets. **AG**

Can sharks live in freshwater rivers?

DIANA ALBERTSON, SOUTH CAROLINA, USA

Most can't, but there are five shark species in the genus *Glyphis* that have adapted to live in the rivers of India and southeast Asia. The bull shark is able to move between salt and freshwater by adjusting the concentrations of urea and trimethylamine oxide in its blood. It takes a few days to make the change as the shark moves up or down the estuary. **LV**

The coast-dwelling bull shark can live in both salt and freshwater

What's the fastest police car in the world?

BEN GOODWIN, LEWES

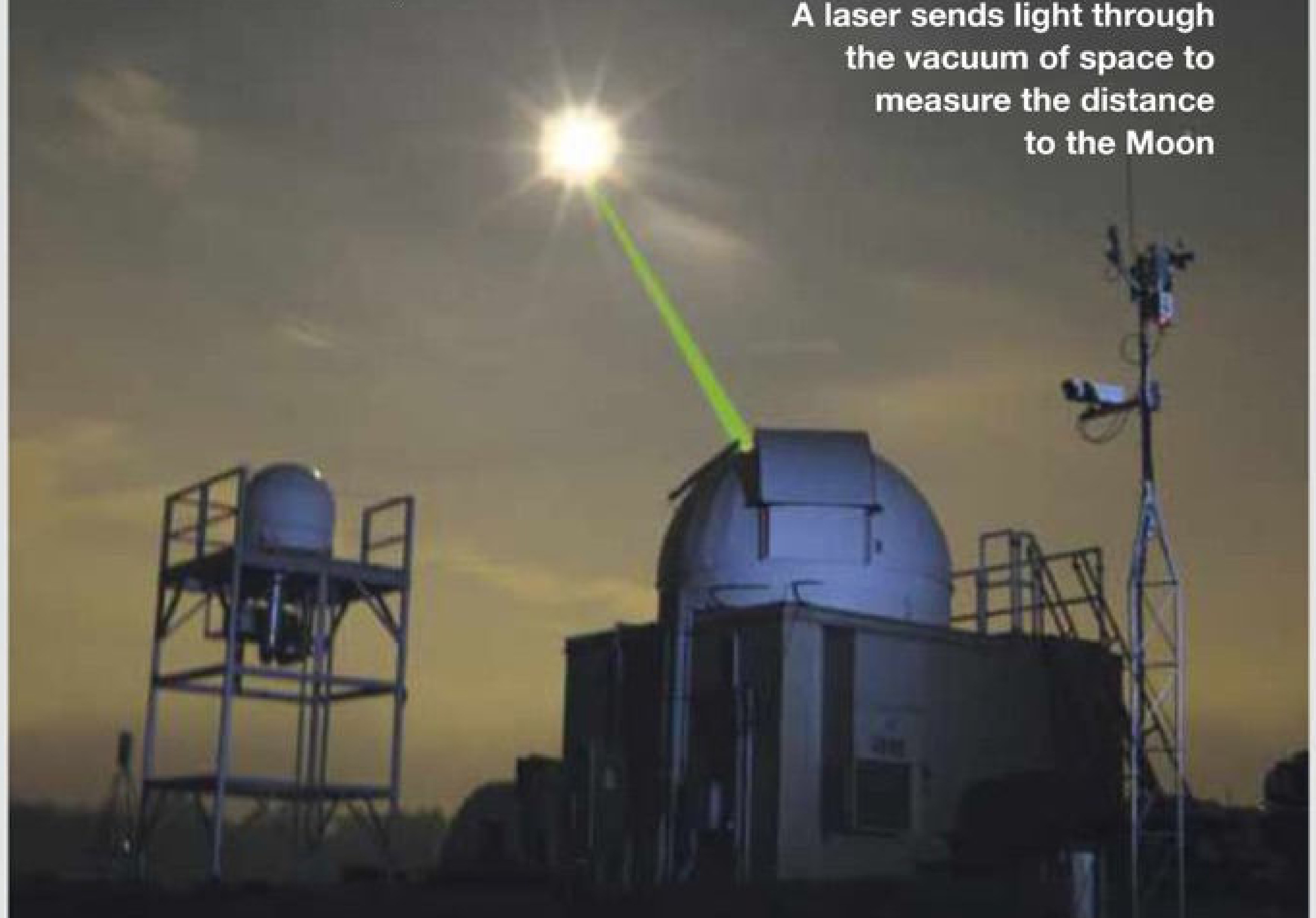
We'd suggest you don't try outrunning the police in Italy, especially if the officers are in the force's most prized motors, a couple of Lamborghini Gallardo LP560-4s. They have 5.2-litre V10 engines, accelerating from 0 to 96km/h in 2.5 seconds. The car's top speed is 320km/h.

But as much as I love fast cars, as a biker I'm more taken with the UK's fastest police bike. The US police use it, too. It is the fearsome Suzuki Hayabusa: with its 1300cc engine, it is the world's fastest production bike, capable of 313km/h. It'd almost give the Lamborghini a run for its money. **GM**

Lamborghini Gallardo

Why is the speed of light constant?

ALAN EDGINGTON, RAMSGATE



A laser sends light through the vacuum of space to measure the distance to the Moon

It isn't. When it passes through some mediums, such as water, it slows down considerably. In the case of diamond, its speed is cut by over 50 per cent. But according to Einstein's Special Theory of Relativity, the speed of light in the vacuum of empty space is said to be the same for all observers, at just short of 300,000km/s.

This is undoubtedly weird, as every other speed is measured relative to something else. For example, a train can move at 150km/h relative to someone on a platform, but to the train's passengers its speed is pretty much zero. The speed of light is no ordinary speed, however: it's a universal constant that emerges from the laws of physics.

Specifically, it's the speed at which electromagnetic waves travel through the vacuum of space – and its value can be predicted by equations unifying our understanding of electricity and magnetism, as discovered over 150 years ago by the Scottish physicist and mathematician James Clerk Maxwell. **RM**

ESA, SUPERSTOCK, GODDARD SPACE FLIGHT CENTER/TOM ZAGWODZKI, SUPERSTOCK, THINKSTOCK, RICHARDPALMERGRAPHICS.COM

How will Earth be filmed from space?

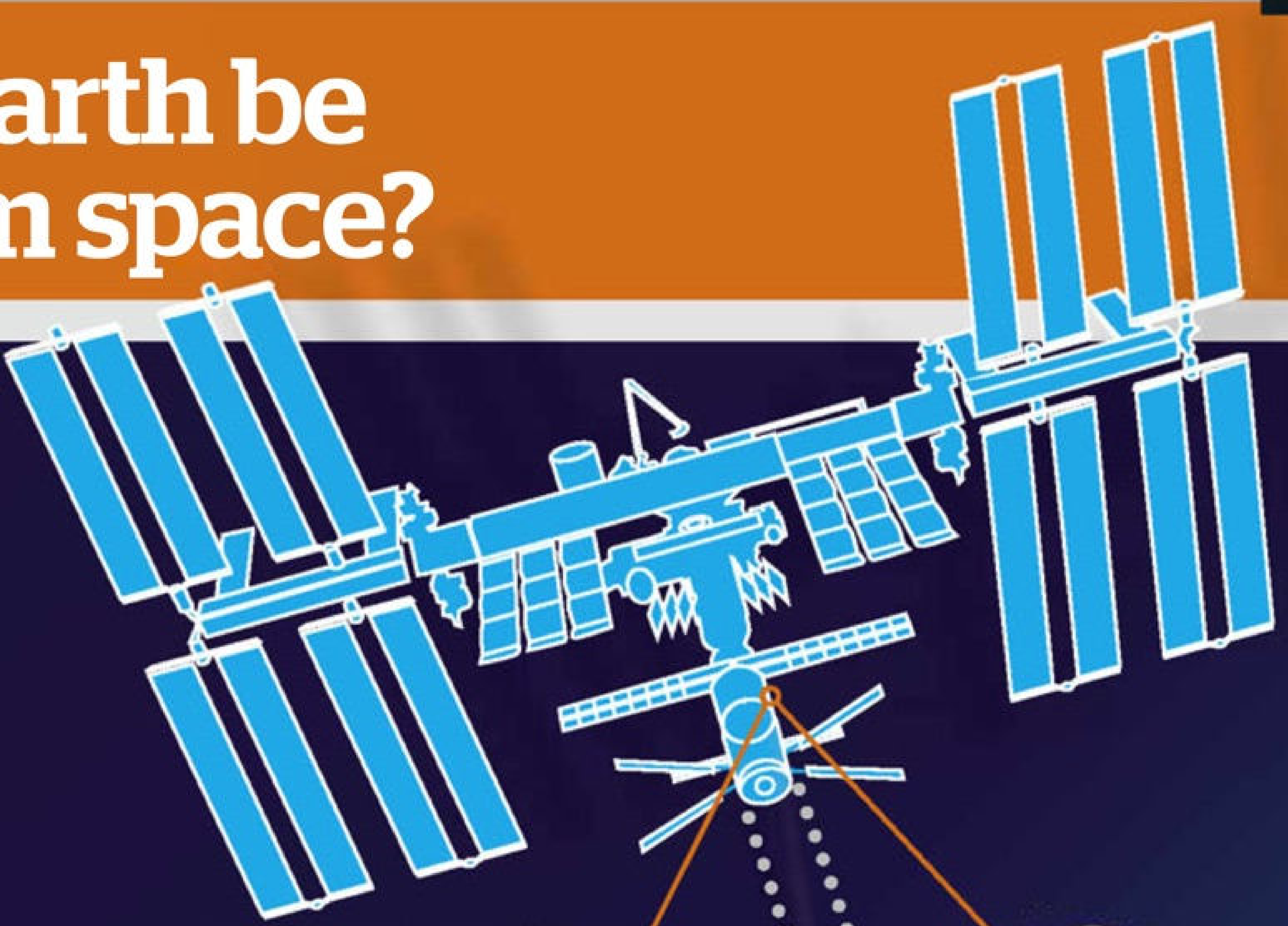
From early 2013 onwards, you'll be able to watch images and video footage of the Earth taken from space, for free. Unlike YouTube videos or Google Earth, the footage being streamed will be almost live.

Images and video will be captured by two cameras flown into orbit by the Canadian company UrtheCast in late 2012. They'll be attached to the Russian module of the International Space Station (ISS). From this vantage point 350km above Earth, the cameras will survey the ground below as they make 16 orbits per day. The ISS's orbit takes it between 52 degrees north and 52 degrees south, thereby covering almost all inhabited areas.

The cameras were designed and built by the UK's Rutherford Appleton Laboratory. The medium-resolution camera takes still images while the high-resolution camera captures video that shows detail as small as 1m across, which is similar to that of Google Earth. To ensure they're pointing in the right direction, and to cope with vibrations on the Space Station, the cameras will be linked to star trackers. These are small cameras that take images of space and locate patterns of stars in order to calculate which way the main cameras are pointing.

The cameras will capture raw data and compress it using the JPEG2000 algorithm. Data from each camera will then be stored on a computer and transmitted when the Station is in sight of a receiver on the ground. This will happen at least once per orbit, or every 90 minutes.

From the receivers, the data will be uncompressed and uploaded to servers. On the UrtheCast website, you'll be able to fast-forward, pause, rewind and skip the near-live footage. You'll also be able to tag segments of video on Facebook and Twitter, and track the Space Station's position to see when it will next pass over an area of interest. *urthecast.com*

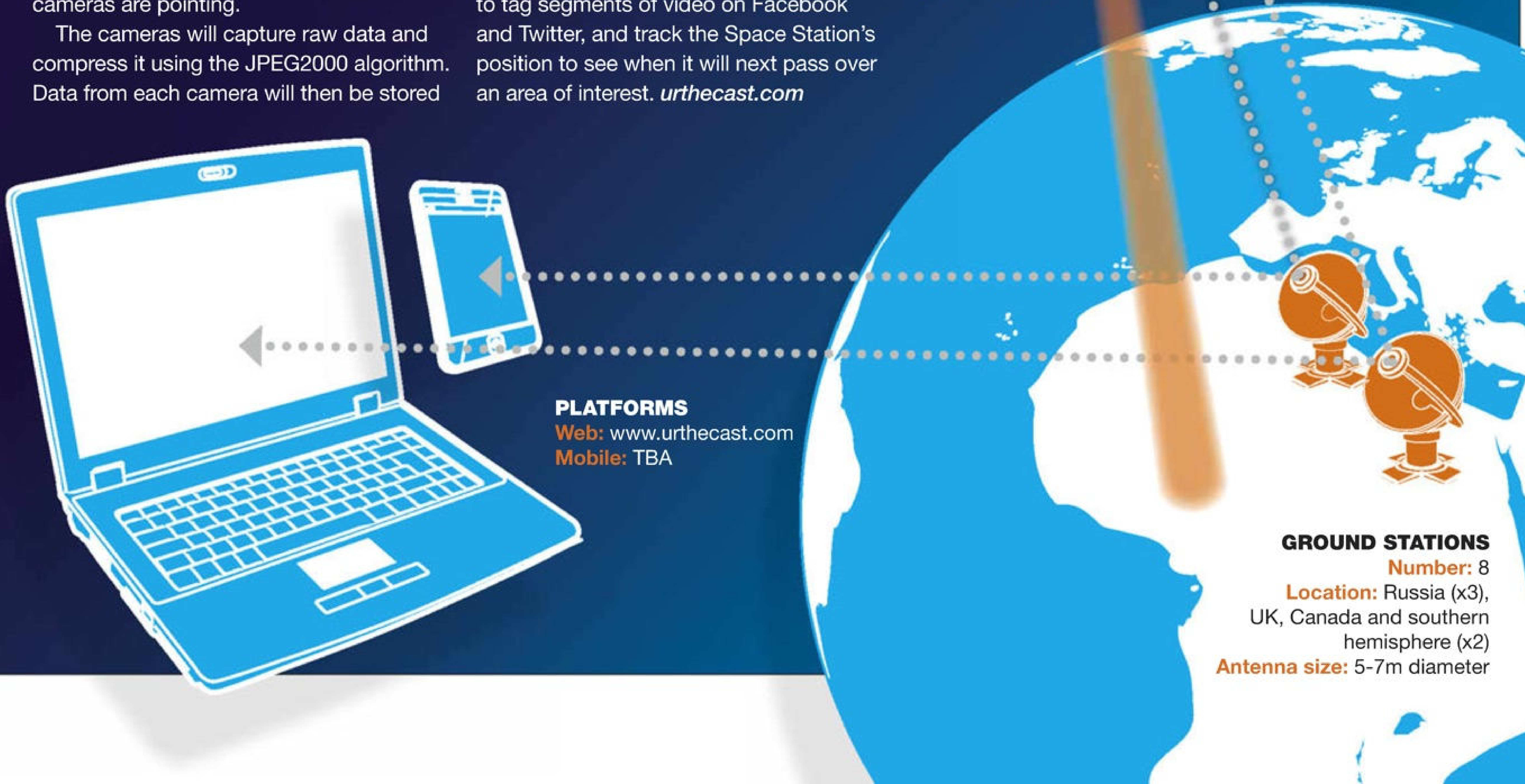


MEDIUM-RESOLUTION CAMERA
Takes: Still images
Area of ground captured: 47km across
Resolution: 5.4m x 6.2m

HIGH-RESOLUTION CAMERA
Takes: Images and video
Area of ground captured: 5km x 3.4km
Resolution: 1.1m
Video: 3.2fps

GROUND COVERAGE
Size of area covered: 47km across (still camera) at 350km altitude

DOWNLINK
Radio frequency: 8GHz
Data rate: 100Mbps



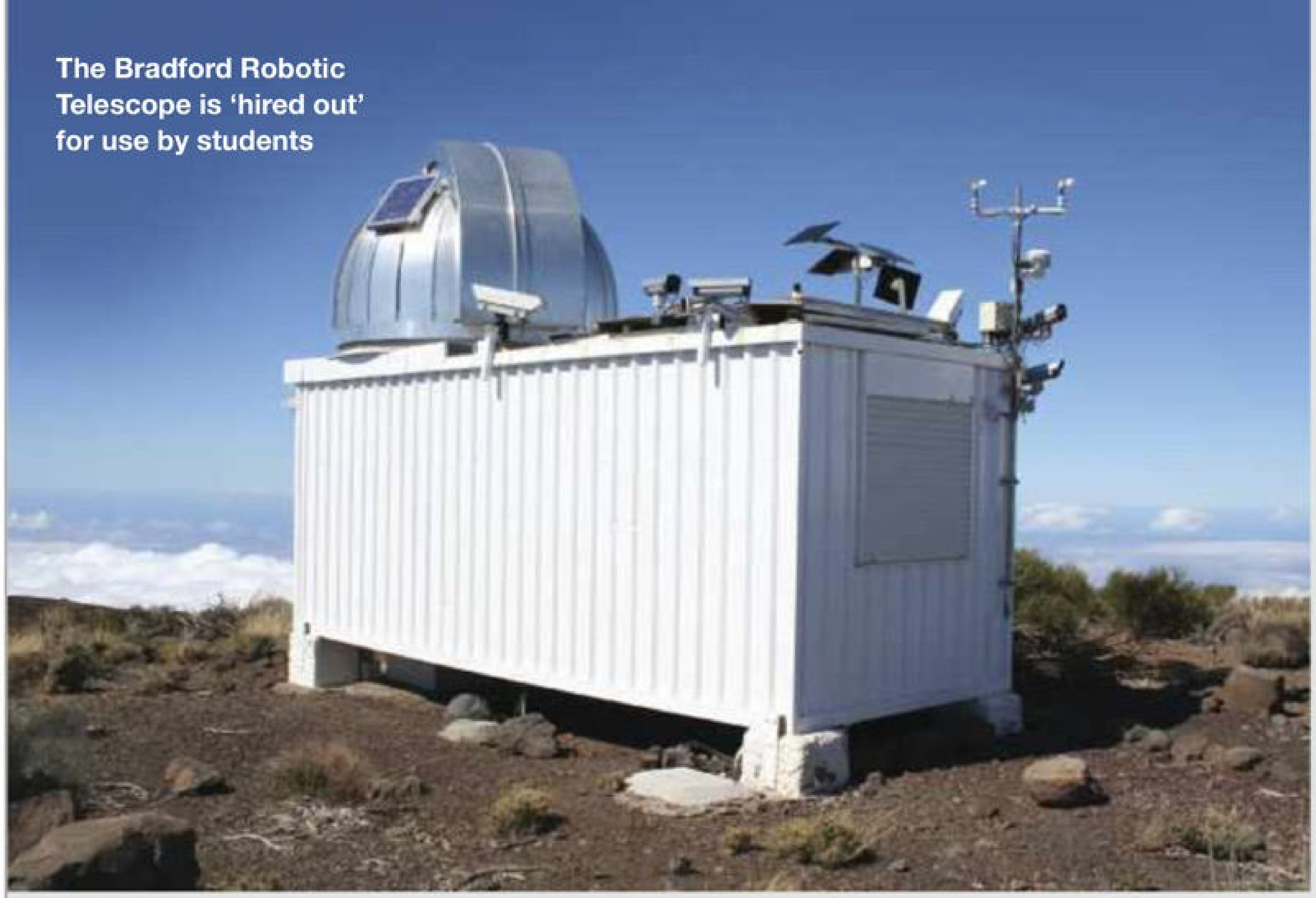
PLATFORMS
Web: www.urthecast.com
Mobile: TBA

GROUND STATIONS
Number: 8
Location: Russia (x3), UK, Canada and southern hemisphere (x2)
Antenna size: 5-7m diameter

Is there such a thing as an online telescope?

RICHARD O'NEILL, GLASGOW

Yes. The Bradford Robotic Telescope at the Teide Observatory in Tenerife, owned by the University of Bradford, works in the visible spectrum and is used largely by schools, who access and control it via its website, www.telescope.org. The Faulkes Telescope Project (www.faulkes-telescope.com) operates two telescopes – one in Hawaii, one in Australia – on a similar basis. A third option is the MicroObservatory, a network of five automated telescopes developed at the Harvard-Smithsonian Center for Astrophysics. Over the web, users can select targets such as planets or galaxies, then set parameters like exposure time or colour filters. Images are emailed back within a few days. See http://mo-www.cfa.harvard.edu/OWN/index.html **GM**

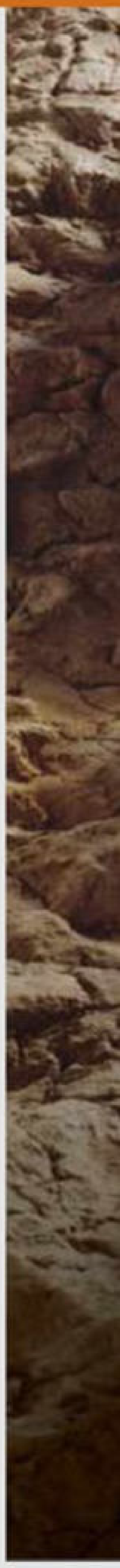


The Bradford Robotic Telescope is 'hired out' for use by students

Why do we rub our eyes when we're tired?

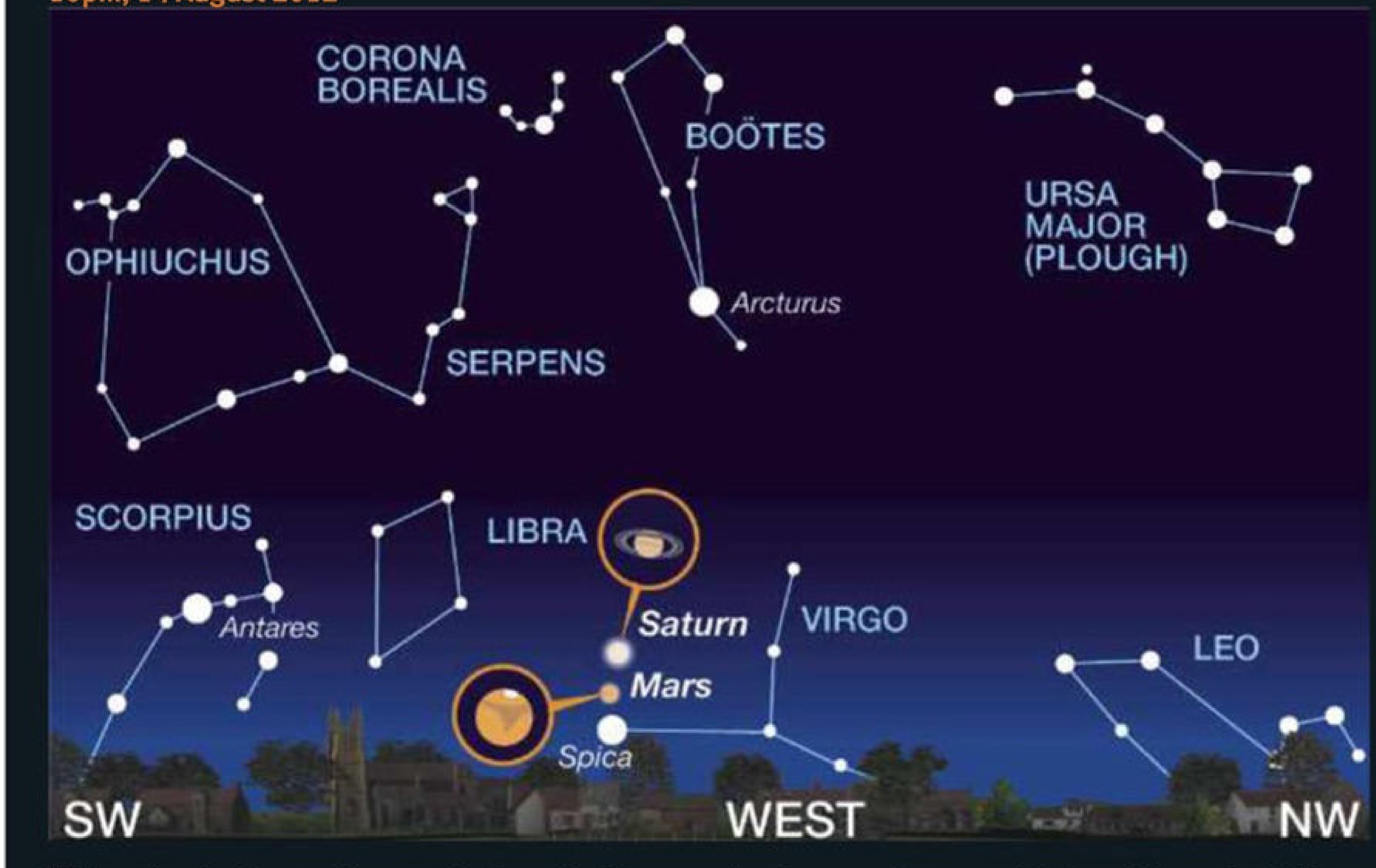
MATTHEW CAHILL, LIVERPOOL

Tired eyes get dry, and rubbing stimulates the lacrimal glands to produce more fluid. Tiredness also closes your eyes, so you may rub to keep them open. Finally, there's a connection between the muscles that move your eyes around and your heart. When these muscles are stimulated, a reflex slows the heart. This might be relaxing if you feel very tired. **SB**



Skywatching with astronomy gurus Heather Couper and Nigel Henbest

10pm, 14 August 2012



With a clear horizon to the west, look out for Mars passing between Saturn and Spica mid-month. Brilliant Arcturus lies directly above, with the familiar Plough to the right and sprawling Ophiuchus to the left.

What can I see this summer?

- **12-13 August, northeast, all night**
August sees the appearance of the Perseids meteor shower. These fragments of Comet Swift-Tuttle, which crash into our atmosphere at over 200,000km/h, peak over this period. Expect to see up to 80 shooting stars an hour under clear conditions.

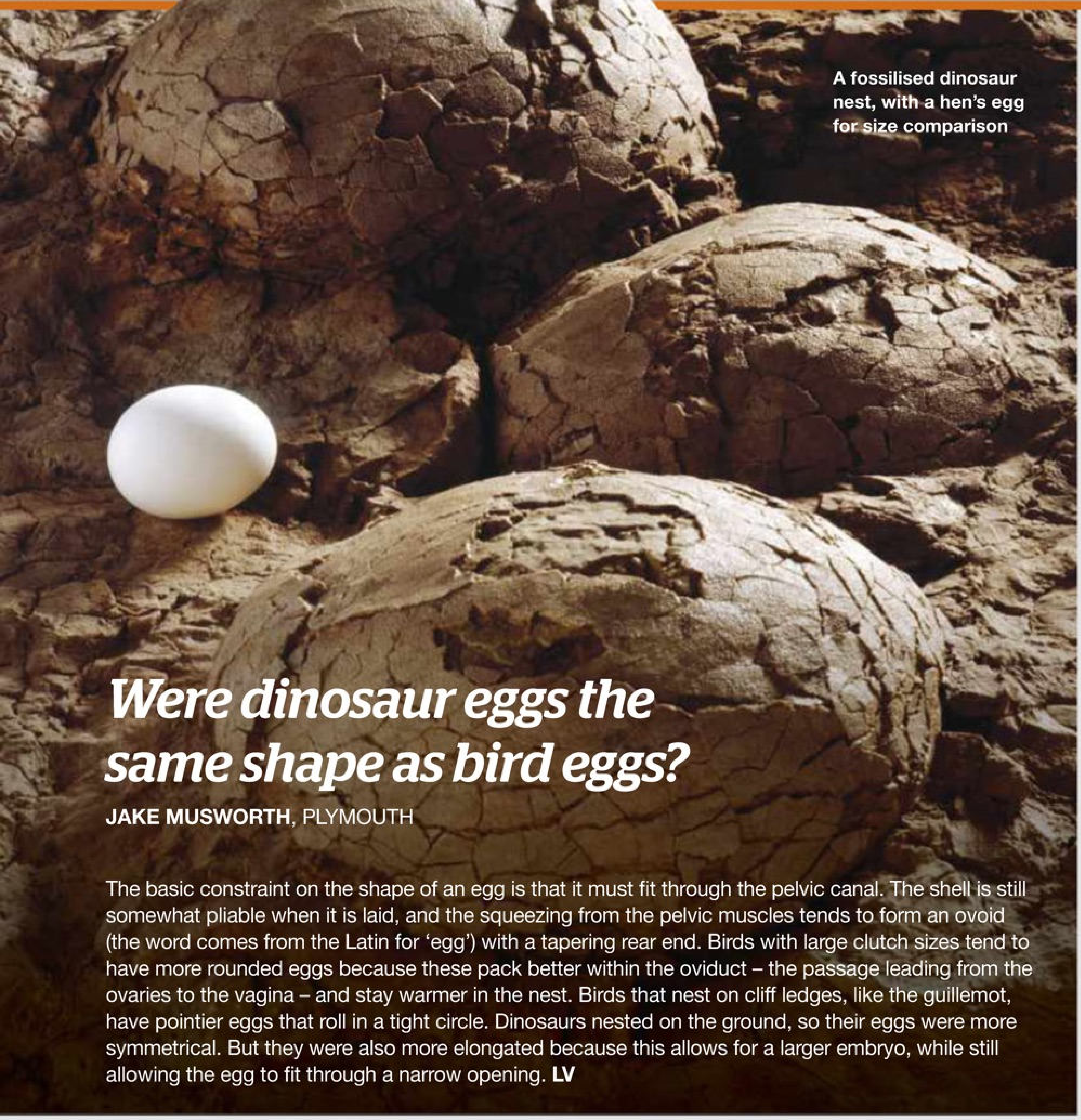
- **13-14 August, west, 10pm**
Very low in the west, blue-white star Spica, red Mars and yellow Saturn all line up. Use binoculars to bring out the colours.

- **15 and 16 August, east, before sunrise**
On 15 August, dazzling Venus rises four hours before the Sun. It's so bright it can cast a shadow! The next morning, its diminutive cousin Mercury – the closest planet to the Sun – puts in a fleeting appearance. Pick it out just to the upper left of the crescent Moon.

Watch *The Sky At Night* on BBC One. Check radiotimes.com for details

BBC one

DAN HEDGES/UNIVERSITY OF BRADFORD, THINKSTOCK, SUPERSTOCK, GETTY, ILLUSTRATION BY PAUL WOOTTON



A fossilised dinosaur nest, with a hen's egg for size comparison

Were dinosaur eggs the same shape as bird eggs?

JAKE MUSWORTH, PLYMOUTH

The basic constraint on the shape of an egg is that it must fit through the pelvic canal. The shell is still somewhat pliable when it is laid, and the squeezing from the pelvic muscles tends to form an ovoid (the word comes from the Latin for 'egg') with a tapering rear end. Birds with large clutch sizes tend to have more rounded eggs because these pack better within the oviduct – the passage leading from the ovaries to the vagina – and stay warmer in the nest. Birds that nest on cliff ledges, like the guillemot, have pointier eggs that roll in a tight circle. Dinosaurs nested on the ground, so their eggs were more symmetrical. But they were also more elongated because this allows for a larger embryo, while still allowing the egg to fit through a narrow opening. **LV**

What causes menopausal hot flushes?

CARLA REDHEAD, WEYMOUTH

Hot flushes are the result of complex hormonal changes that are still being investigated. The menopause begins when the ovaries start producing less oestrogen. This affects other hormones, including raising levels of gonadotrophins secreted by the brain's pituitary gland. Gonadotrophins are involved in temperature regulation as well as reproduction, so this imbalance causes the hypothalamus in the brain to act to reduce temperature: by sweating more, speeding up your heart rate and dilating blood vessels in the skin, so that you look 'flushed'. The suddenness of the effect can create dizziness and nausea as well. Even so, you only *feel* hotter. **SB**

Hot flushes are caused by a change in the balance of hormones in a woman's body

What makes some headphones better than others?

TAHA EL ZEIN, QATAR

Ultrasone's Edition 8 Ltd headphones: a mere £1,349

The most crucial factor is the quality of the miniature loudspeakers inside. Most models can match the range of human hearing at 20Hz-20kHz, but only the better ones have a flat response so that low, mid and high frequencies are reproduced equally faithfully. The expensive sets use more refined materials, especially when it comes to the muffs that sit over the ears, and beat their cheap counterparts for noise isolation and comfort. **GM**

Why is it impossible to reach absolute zero?

SARAH COLEY, EDINBURGH

Absolute zero, or –273.15°C, is unattainable because this temperature also represents a state of zero entropy – roughly speaking, 'disorder' – for any material. The less disorder within it, the harder it is to reduce further, and it would take an infinite amount of time and effort to eliminate it all. Scientists have come very close, though: in 1999 researchers in Finland got within one billionth of one degree Centigrade of the ultimate value. **RM**

NEXTMONTH

How do tins preserve food?

Were humans vegetarian before cooking was discovered?

Why is hot water better for washing?

At their peak, how many dinosaurs roamed the Earth?

Do other animals perceive colour in the same way we do?

On sale: 23 August

If you can't wait until then, check out the Q&A archive

sciencefocus.com/qanda

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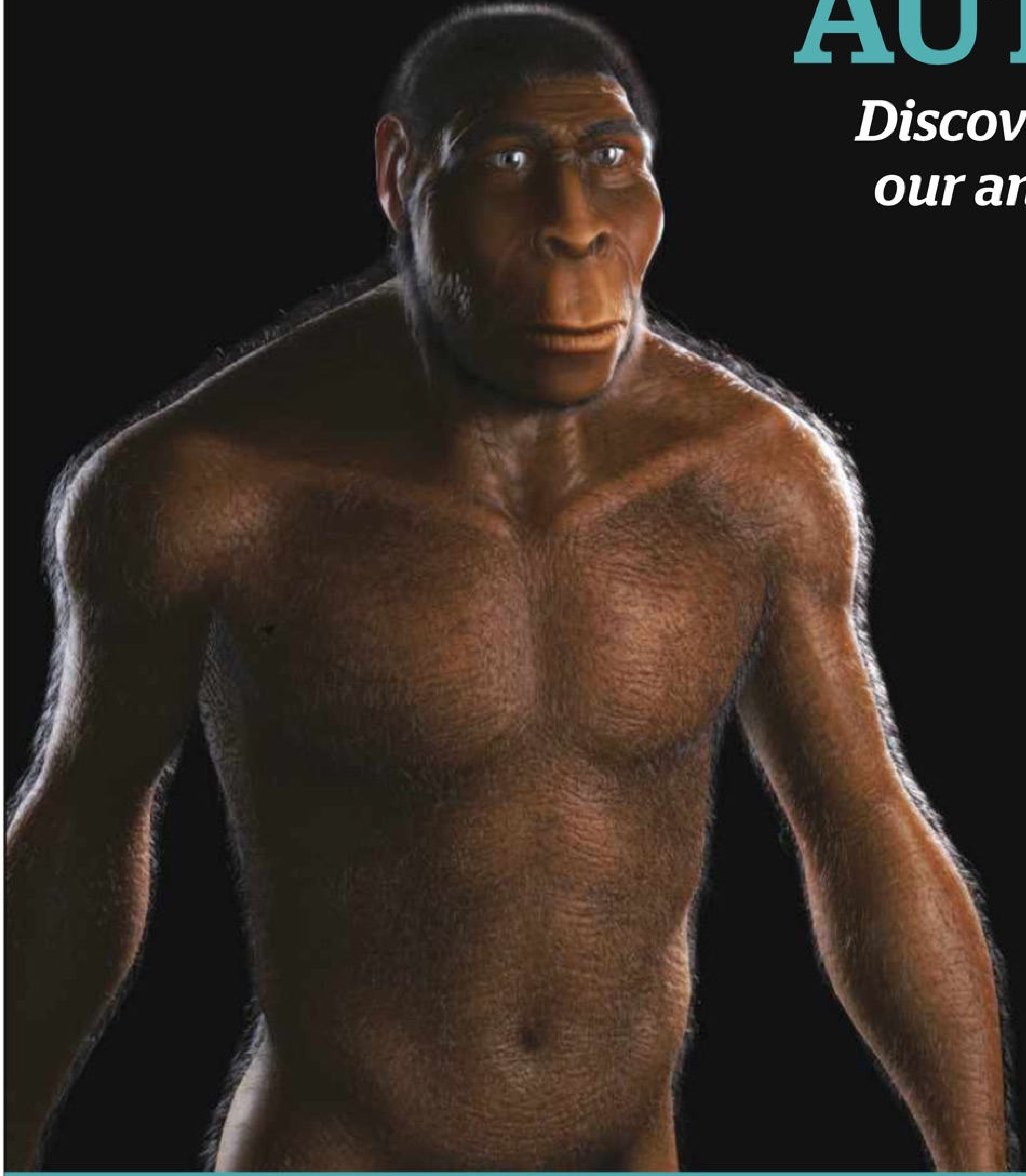
FOCUS

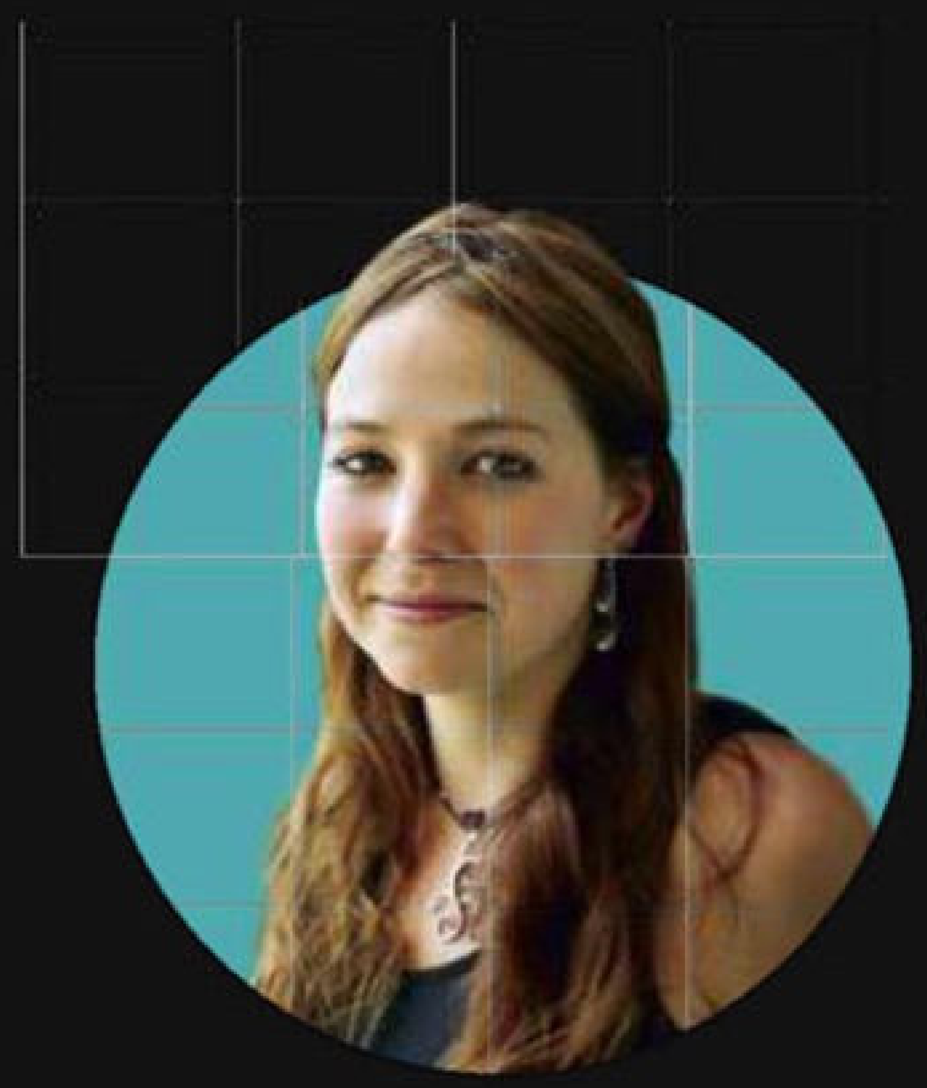
SEPTEMBER ISSUE

ON SALE 23/08/12

PREHISTORIC AUTOPSY

Discover the secrets of our ancient ancestors





BBC TWO

Accompanies the BBC Two series with Prof Alice Roberts

PLUS

- *The lab that breeds lightning*
- *Could* Total Recall *ever come true?*
- *Incredible plans for cities at sea*
- *The revolutionary Raspberry Pi*

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Entrants must be UK residents (inc Channel Islands) aged 18 or over. Immediate Media employees are not eligible to enter. By entering participants agree to be bound by these terms and conditions and that their name and county may be released if they win. Only one entry permitted per person. No responsibility is accepted for lost, delayed, ineligible or fraudulent entries. The closing date and time are as shown on page 107. Entries received after that will not be considered. Entrants must supply their full name, address and daytime phone number. Immediate Media (publisher of *Focus* magazine) will only ever use personal details for the purposes of administering this competition unless you permit otherwise. Read more about the Immediate Privacy Policy at www.immediatemedia.co.uk/privacy-policy. The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown on the Crossword page. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. The name and county of residence of the winners will be published in the magazine within three months of the closing date. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.

The Guide

Everything for the clued-up consumer

Don't miss

Tablet computers go head-to-head 84
Turn your smartphone into a laptop 86
First look: Parrot Zik headphones 88
Videoconferencing with Google Hangouts 99

THE LIFE SCIENTIFIC

Jim Al-Khalili tells Daniel Bennett about the second series of his Radio 4 show

Not a science documentary. That's how Jim Al-Khalili describes his returning Radio 4 series *The Life Scientific*, a show that celebrates the motivations, inspiration and life stories of some of the brightest minds in science today.

If you caught the last series you'll appreciate what Jim means. While we frequently celebrate the groundbreaking experiments and ideas dreamed up by the likes of Sir Paul Nurse, Jocelyn Bell Burnell and James Lovelock, their personal stories are often relatively unknown. Take Sir Paul Nurse, for example, the Nobel Prize-winning geneticist, who in the last series revealed how he discovered in his 50s that the woman he had grown up believing was his older sister was in fact his biological mother. Or Dame Jocelyn Bell Burnell, who discussed the challenges of working in a male-dominated discipline in the 1960s and '70s, and how she felt after missing out on a Nobel Prize.

There's a lighter side, too. One of Jim's favourite moments from the last series was when Antarctic biologist Lloyd Peck recounted how the scientists and divers play upside-down football together under the ice. "You might imagine these people as very serious, boring and only interested in the data," Jim explains, "but this really showed that they weren't." And in case you're wondering, upside-down football involves full diving gear, sheet ice and some nimble footwork.

For this new series, Jim has again sought out the great and good, including none other than Richard Dawkins. "We talked about his early work in genetics, where his ideas came from and how his book *The Selfish Gene* was received. But we're also talking to young, up-and-coming scientists who will hopefully win Nobel Prizes in the future."

He means guests like Molly Stevens, who heads up the regenerative medicine lab at Imperial. She oversees engineers, chemists and medics who are trying to create human tissue and bones artificially to usher in a new era in medicine. Other interviewees will include Pat Wolseley, Martin Siegert, Sunetra Gupta, Hugh Montgomery, Ann Dowling, Steve Jones and Andrea Sella. So why should we care about their lives?

"These scientists are just as influential in society and culture as their counterparts in the arts," says Jim. "They may have done things that have transformed our lives, yet we often know so little about them."

The first episode of The Life Scientific *airs on Radio 4 on 7 August, featuring an interview with Richard Dawkins*

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The Review Squad

Professor Steven Rose
Professor Rose is a biologist and the author of over a dozen popular science books. He reviews Frances Ashcroft's *The Spark Of Life* on p100.

Daniel Bennett
This month, Dan's been testing Parrot's new noise-cancelling Zik headphones, designed by Philippe Starck. Read his verdict on page 88.

Robert Banino
Former *Focus* staffer Rob is a full-time cycling nut – so who better to put the latest electric bikes through their paces? Find out what he thought on p90.

Jane Douglas
Gamespot UK section editor Jane has been off on a journey this month. *Fable: The Journey*, that is, as she tests out the pioneering new Xbox game.

Bill Thompson
Our resident web guru asks if we're being too trusting with our personal data, and gets excited by Project Noah, a new 'citizen science' ecology website.

BATTLE OF THE TABLETS

As Microsoft and Google unveil their new rivals to Apple's iPad, we take a look at how the contenders shape up...

GOOGLE NEXUS 7

If the cost of a tablet is what's stopped you from buying one so far, then the Nexus's £159 price tag is likely to be its most attractive feature. For this bargain price you might expect Google to have scrimped on features, but that's not the case.

The Nexus 7 carries a full-HD, seven-inch display, a quad-core Tegra processor, and a battery that will survive nine hours of video playback. It's also the only tablet currently available running Jelly Bean, the newest tablet-optimised version of the Android operating system, though it probably won't be for long. Jelly Bean comes loaded with apps that have been designed for a seven-inch screen.

It seems the only things you don't get for your money are an SD card slot for expanding your memory, and a rear-facing camera. The lack of SD might disappoint, but it won't present a problem if you fully embrace Google's cloud services.

A bigger drawback might be that Google Play – the new name for the Android Marketplace – is mostly populated with apps designed for phones and not larger devices like the Nexus 7, perhaps leaving you feeling a little short-changed on the full tablet computing experience. The iTunes App Store, by comparison, has a healthy library of books, games and apps specifically created for Apple's large-screened device.

When it goes on sale later this year, the Nexus 7 will easily be the best seven-inch tablet available, unmatched on performance and price. And if you hanker after a bigger screen – closer to the proportions of the iPad – then we suspect a 10-inch Nexus is likely to be in the works for next year.

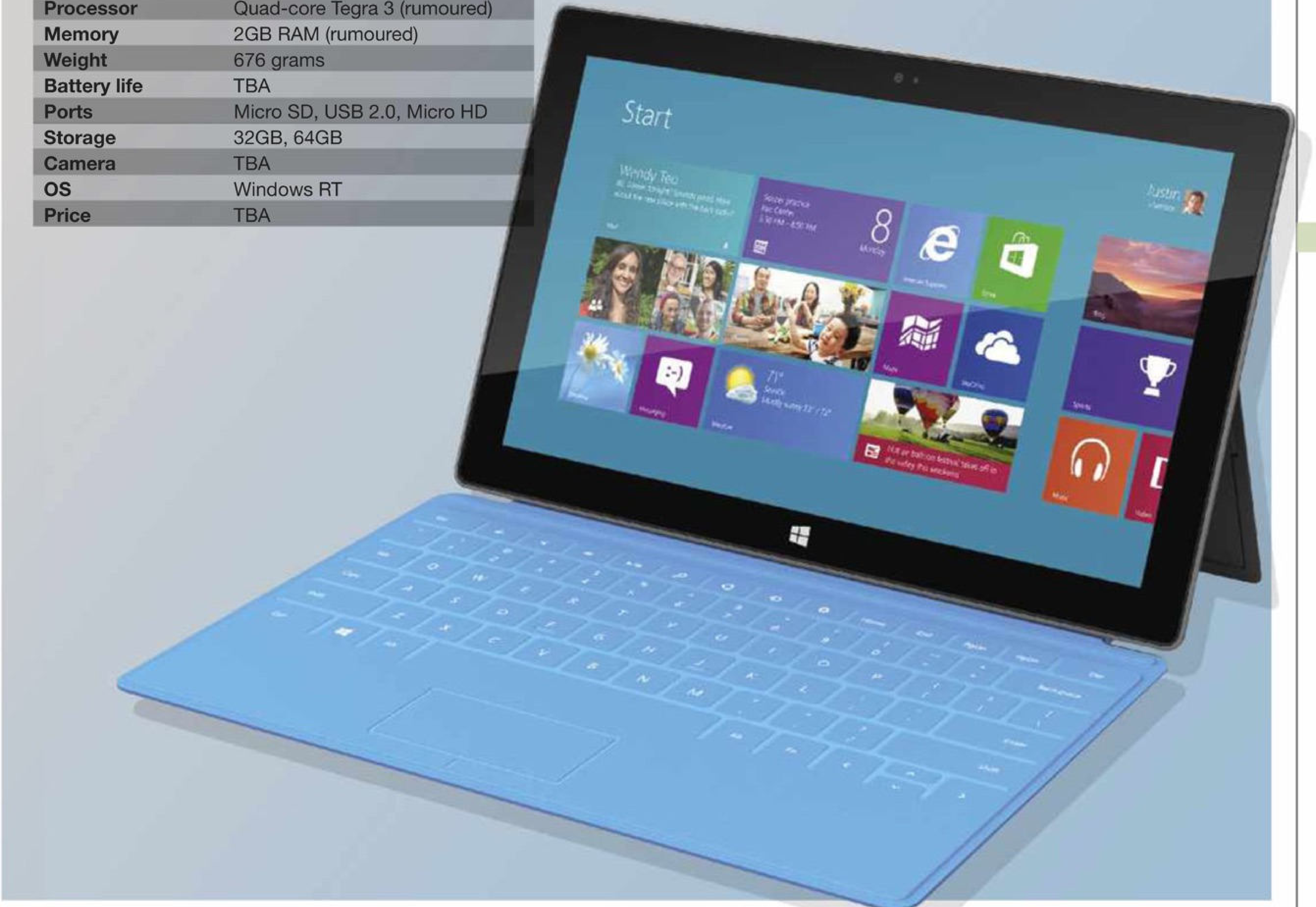
Price: £159 (8GB)/£199 (16GB)
play.google.com

GOOGLE NEXUS 7

Screen size	7 inches
Screen resolution	216 pixels per inch
Processor	Quad-core Tegra 3
Memory	1GB RAM
Weight	340 grams
Battery life	9 hours video/10 hours web/300 standby
Ports	Micro USB
Storage	8GB/16GB
Camera	1.2-megapixel, front-facing
OS	Android 4.1 (Jelly Bean)
Price	£159/£199

MICROSOFT SURFACE

Screen size	10.6 inches
Screen resolution	TBA
Processor	Quad-core Tegra 3 (rumoured)
Memory	2GB RAM (rumoured)
Weight	676 grams
Battery life	TBA
Ports	Micro SD, USB 2.0, Micro HD
Storage	32GB, 64GB
Camera	TBA
OS	Windows RT
Price	TBA



MICROSOFT SURFACE

This isn't Microsoft's first attempt at making a tablet PC – not by a long chalk. Way back in 1991, the company unveiled Windows for Pen Computing, an unwieldy operating system that let you control Windows with a stylus on a device akin to a paving slab. This and the attempts that followed were all fatally flawed: attempting anything but the simplest task required a lot of squinting, fumbling and swearing. Without a mouse and keyboard, the Windows interface was often a nightmare to use.

Now, some 20 years later, it seems as though Microsoft has learnt its lesson. The new Windows 8 operating system (RT for tablets) is designed first and foremost with touch controls in mind. The icons are large and colourful, the number of 'clicks' or finger-presses is minimised and a lot of information is available at a glance. And just in case anyone does find touchscreen controls tricky to contend with, the new Surface tablets come with a detachable keyboard and touchpad for a more traditional computing experience.

So far, Microsoft has been rather coy about what's inside its new device, but it's likely to carry a Tegra 3 chip, which is typically used by the latest Android tablets. There's also going to be a premium model that we're told will use one of Intel's Ivy Bridge processors, which are more usually found powering ultrabooks.

As it stands, the Surface could have one major advantage over the iPad. Its additional keyboard, touchpad and ports could make it far more adept in the workplace than the iPad, and ideal for writing emails, editing documents and sharing files.

Price: £TBC
www.microsoft.com

Objects of desire

Clam up!

This ClamBook shell is little more than a keyboard and a screen, which is why it's so thin. The device draws all it needs – processing power, memory and internet connectivity – from your iPhone or Android smartphone. Dock your phone and it gives you access to apps including Firefox, webmail and a media player. It's a limited selection for now, but through its web browser you can also access cloud apps like Google Docs. This approach to computing is making more sense now that you can carry as much processing power in your pocket as your laptop had just a couple of years ago.

ClamBook
Price: TBC
clamcase.com

Paranoid android

Giving a robot cleaner a personality and the ability to speak sounds like a recipe for disaster, if you ask us. But that hasn't stopped Sharp from creating this sensitive robot vacuum cleaner. Cocorobo understands and responds to 36 voice commands. It's also programmed to have different 'moods' which it acts out in its movements and tone of voice – so you'd be well advised to ask how its day has been before issuing orders. At the moment it's only available in Japan, but Sharp says it'll be cleaning European floors soon.

Cocorobo
Price: $1,600 (£1,027) plus P&P
www.sharp.co.jp/cocorobo

Sub-aqua spycam

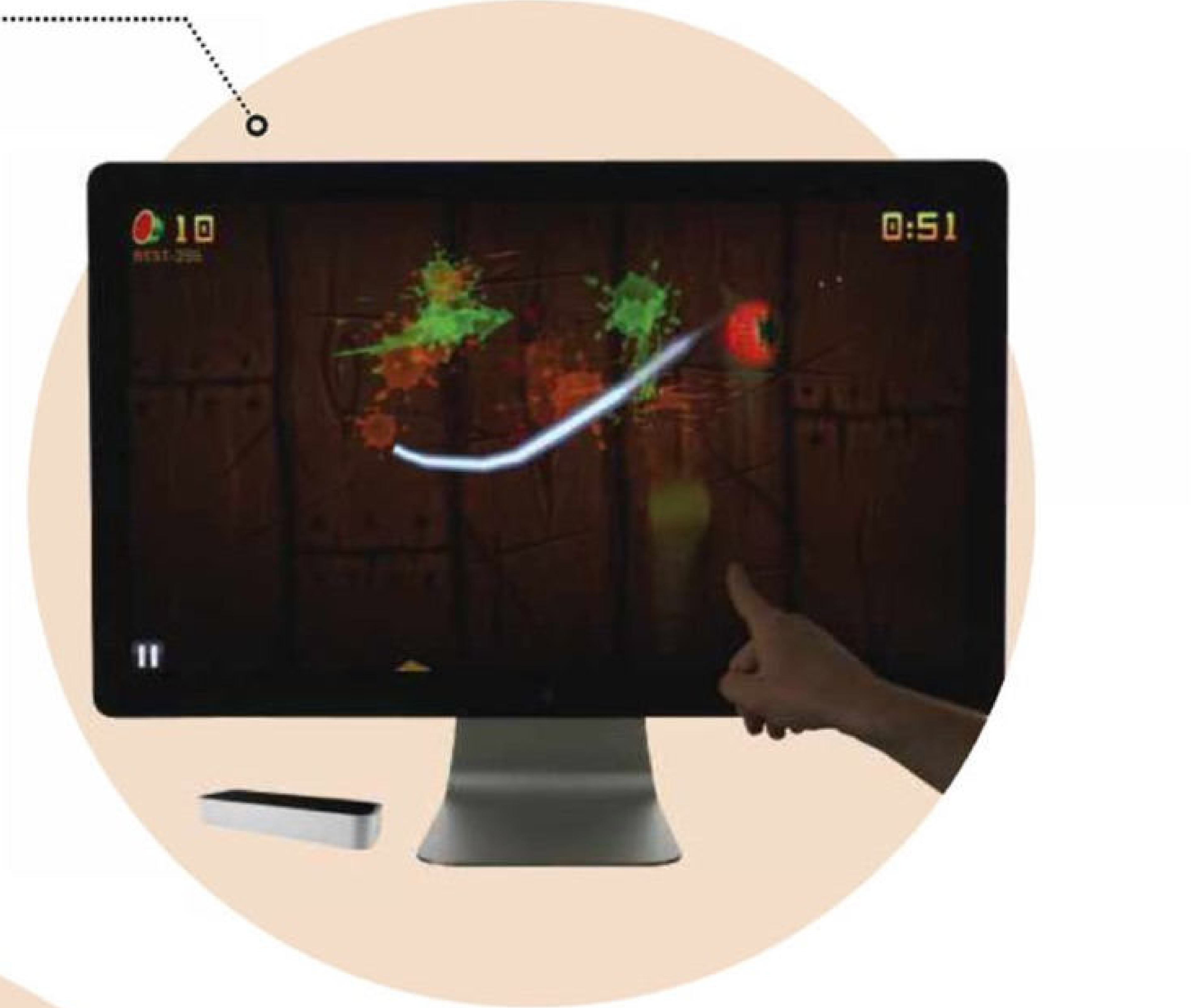
Deep sea diving? There's an app for that. If you dream of exploring underwater worlds like Jacques Cousteau but don't want the inconvenience of getting wet, then this iPad-controlled sub lets you explore the seas from a safe distance. It's got an HD camera mounted on its nose, which sends a video feed through a 75m-long cable to a 'topside box' that stays on dry land and transmits a stream to your tablet via its own wi-fi network.

Hydroview
Price: $3,995 (£2,565) plus P&P
www.aquabotix.com/hydroview

Sleight of hand

This USB stick-sized device promises to offer the *Minority Report*-style controls that Microsoft's Kinect never quite delivered. Instead of monitoring your whole body, the Leap Motion just tracks your fingers and hands so you can manipulate what's on your computer screen with your digits. It monitors the position of your paws using a series of cameras that track infrared dots projected from the device. Clever algorithms then analyse this data to work out exactly where your fingers are in the 3D space in front of the monitor. The result is that you feel like you're reaching into your screen.

Leap Motion
Price: $70 (£45) plus P&P
www.leapmotion.com



Star snapper

While this might look like an ordinary DSLR, the Canon EOS 60Da is actually a camera that's been optimised for astrophotography. Its 18-megapixel sensor has a modified filter that's more sensitive to infrared light, which is typically given off by cosmic nebulae. The sensor itself is also finely tuned to be more sensitive to the lower wavelengths that are required if you want to capture detailed shots of the night sky.

Canon EOS 60Da
Price: £1,174.99
www.canon.co.uk

Tennis trainer

Sensors embedded in the frame of this tennis racket monitor your stroke, the spin of the ball, where the ball hits the strings, the power of your swing and your service speed. These can then be uploaded to your PC via USB, to be analysed and shared before setting a series of targets for your next game. Centre court at Wimbledon next year, maybe?

Babolat Play & Connect
Price: TBC
www.babolat.com

SOUPED-UP SOUNDS

Are these the most high-tech headphones ever?
Daniel Bennett dons the Parrot Zik to find out

What makes these headphones so special?

Despite the pared-back looks – they're designed by Philippe Starck, no less – these Zik headphones are positively crammed with clever technology. They offer Bluetooth and NFC connectivity (just tap them on your phone, and the two devices are instantly paired), as well as a noise-cancellation system, but that's just for starters. Hidden under the surface of the right earcup is something a bit more unusual: a touch-sensitive panel.

Run your finger up or down the surface of the can and it'll increase or decrease the volume; swipe your finger from the back to the front and it'll skip to the next track. It's an effortless way of controlling your music without digging in your pockets for your phone – though I did manage to inadvertently skip tracks when I pulled on a hood to guard the 'phones against the rain.

There's also a conductive pad inside the earpiece that tells the Zik when it's in contact with your skin. Break that contact by taking the headset off and it automatically pauses whatever's playing; stick them back on again and the music resumes. It's supremely intuitive and helpful.

What's the sound like?

The Zik provides a roomy sound that does an incredible job of making you feel like your music is being played right in front of you. The bass is meaty and the treble is accurate and crisp. So whether you're listening to Brahms or Black Sabbath, you'll get a well-rounded sound rich with detail. This isn't much of a surprise considering the £349 asking price; what's unusual is what happens when you fire up the Zik app on your PC or smartphone.

As well as providing an equalizer, the app enables you to shift where your music sounds like it's coming from. Essentially, the Zik will simulate the effect of having a band playing in front of you, which its creators argue is a more natural and therefore less tiring way to listen to music. But while the theory makes sense and the effect is impressive, especially with live recordings, we're just not sure how often we'd use this option.

How effective is the noise cancellation?

The headphones are packed with microphones that sample noise from the outside, which they then negate with an opposing signal. And those microphones haven't gone to waste: these are some of the most effective noise-cancelling headphones we've ever tested.

Even when used outdoors the Zik does a great job of isolating you from the hustle and bustle of the world, letting you really escape into your music. Though you should bear in mind that this possibly makes them a little unsafe to wear anywhere near a busy road.

Should I buy them?

If you travel often and are hankering after some high-end headphones, then the Ziks might be for you. Their sound quality and noise-cancelling tech make the world melt away while you travel from A to B. Though heavy in the hand, they're incredibly comfortable to wear for long stints. They also look the part: Starck has opted for clean lines, making these one of the smartest pairs of headphones money can buy. The Zik's dedicated smartphone app is clever and original, simulating the sound of music being performed in front of you, though the effect may not be to your taste. Best of all, the headphones are filled with new technology that's so ergonomically designed that you barely notice it's there.

Christmas might be a long way away, but these are definitely going on our wish list.

WWW.STUDIO4PHOTO.CO.UK, ILLUSTRATION BY MAGICTORCH

OR TRY THESE...

Atomic Floyd SuperDarts +Remote, £199

If you'd prefer something more compact, these new earphones squeeze two speakers into each earbud to create a fuller, deeper sound than we'd usually expect from in-ears. Though they're not wireless, the cable is Kevlar-lined, making it tougher than your average earphones, plus they come with an in-line remote and mic.

POWERED-UP PEDALLING

Take the strain out of your cycling with an electric bike that gives you a boost. **Rob Banino** saddles up…

How does an electric bike work?

The same way a normal bike does – you pedal it. The difference is an electric bike also has a motor. But it's not effortless, exertion-free riding, it's power-assisted cycling. The motor is there to help get you moving, or keep you moving when the going gets tough, such as when climbing a steep hill. As you pedal, torque sensors detect how much power you're applying and signal the motor to provide a proportionate amount of boost. Don't expect an electric bike to turn you into Valentino Rossi, though – their motors are restricted to 24km/h (15mph) by law. You can go faster if you want to, but the power to do so has to come from your legs alone.

Why not just get a scooter?

To ride a scooter you'll need insurance (from around £10 per month), road tax (starting at £15 for anything up to a 150cc-engined scooter), a course of compulsory basic training and a helmet. Then there's fuel and parking to think about. Electric bikes are a costly investment to begin with, but after that a lock and a helmet are all you need. Granted, you'll need to pay for the electricity to charge it up but that's considerably cheaper than a tank of petrol. Financial concerns aside, electric bikes are a fun but gentle way to enter the world of cycling if busy roads and big hills seem intimidating.

Would I be better off with a normal bike?

Possibly, but it depends on what sort of state you want to be in when you arrive at your destination. If you're going to be pedalling frantically to get to work, you'll walk in panting and covered in sweat. That's fine if you want the exercise and don't mind carrying a change of clothes, but if you want a more leisurely journey then an electric bike is the way to go.

What we tested

Design
How does the bike look? If you're going to be using it for the daily commute you'll be sitting on it day in, day out, so if it's going to turn heads you want it to be for the right reason.

Fun factor
Whether it's got a motor or not, a bike that isn't fun to ride won't get used. So will the bike make you want to get out and hit the road?

Practicality
What's the bike like to live with? It will need to be stored and then retrieved for each journey, so can it be moved about easily when it's not being ridden?

Ride
What is the bike like to ride? Having a motor will help get you going but the bike needs to make you feel comfortable and in control.

WWW.STUDIO4PHOTO.CO.UK

XH HYBRID
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ROCK SHOX
METROPOLIS
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Performance Line

Ebco Eagle LSR-50

£1,599

www.ebco-ebikes.co.uk

+

The Ebco Eagle looks like a bike from the future. With its alloy wheels, LCD 'dashboard' and boxy battery port, of all our test models it's the one that seems the most high-tech at first glance. It's also one of the most sensible bikes here, with accessories like a front mudguard and chain cover to keep you and your clothes clean during your commute. Front suspension takes the worst of the jolts out of the ride and disc brakes keep you in complete control of your speed at all times.

The motor is mounted in the front wheel's hub and has four speeds – economy, normal, climbing and turbo – that you select using the small control pad placed by your left hand.

−

Despite its four speeds, the Eagle never really seems to take flight. The power assistance is smooth, but while it'll take you up to the same 15mph max (24km/h) speed as the other bikes, there's little exhilaration involved, possibly because of the upright sitting position. It's fine for just pootling along, but too sedate to be much fun. With the motor in the front wheel and battery at back, it needs to be lifted carefully in and out of the house as it's liable to tip over.

Design: ●●●●○
Ride: ●●●○○
Practicality: ●●●○○
Fun factor: ●●○○○
Overall: 12/20

Drive system:
TranzX PST 250W front hub motor, three power-support modes and turbo button
Battery: 36V lithium polymer
Range: 70-80km (43-50 miles)
Charge time: 5-6 hours
Gears: Shimano Alivio, 8-speed
Weight: 26.8kg

AVE XH 7

£2,799

www.ave-bikes.de

+

The XH 7 is unique among the bikes here in that it doesn't house its motor in either the front or back wheel. Instead, it uses a unit that sits in the centre of the bike and drives the axle that connects the cranks. It's a superb piece of kit that feels torque-y and powerful, but manages to deliver the drive incredibly smoothly.

You get the impression the XH 7 could roll over anything standing in your path: it's built like a tank. Big balloon tyres and front and rear suspension make for a slightly bouncy ride, but this evens out on cobbled streets and lumpy lawns. Cruising along, the XH 7 never fails to feel cushioned and controllable, and always puts a smile on your face.

−

The XH 7 will take short slopes and ramps in its stride, but while it can handle steeper or longer climbs, it feels a little less at home in such circumstances. Having to carry a battery and a motor makes all electric bikes heavy and this one is no exception, but putting both units in the middle of a full-suspension frame does make the ride a little wallowy. It also makes it tricky to tip up on its back wheel when you need to move it about.

Design: ●●●●○
Ride: ●●●●○
Practicality: ●●○○○
Fun factor: ●●●●●
Overall: 15/20

Drive system:
Bosch 250W centre-drive motor
Battery: 36V Li-ion
Range: 95km (59 miles)
Charge time: 5-6 hours
Gears: Shimano SLX, 10-speed
Weight: 23.7kg

WWW.STUDIO4PHOTO.CO.UK

Drive system:
A2B Ultra 250W motor
Battery: Sanyo Li-ion
Range: Up to 64km (40 miles)
Charge time: 4-5 hours
Gears: SRAM 3.0, 7-speed
Weight: 27kg

Hero Eco A2B Hybrid 24

£1,999

www.heroeco.com

+

You need a key to switch on the Hybrid 24. It's a small electronic fob and without it the Hybrid is simply a bike with a battery and motor bolted onto it. But touch the fob against the tiny LCD dashboard and you turn on the power assistance system, which consists of a 250W motor that will propel you along at speeds of up to 24km/h (15mph).

Aside from the 'key-operated ignition', what makes the Hybrid special is its regenerative braking capability. Every time you pull the brakes, the electric motor stops driving the back wheel and starts working as a generator. It uses the rotational force acting against it to produce power that is then stored in the battery, giving it up to seven per cent more charge at no extra cost.

−

The Hybrid is the most utilitarian-looking bike here, with a design that favours function over form. But while the battery mount is one of the most convenient to use, it's not ideally located. Placing it over a back wheel within which sits an equally weighty motor makes for a very heavy rear end, resulting in a ride that feels somewhat ponderous. It also means it's unbalanced when you lift it, so the only stable way of moving it around is to roll it on its rear wheel.

Design: ●●●○○
Ride: ●●○○○
Practicality: ●●●○○
Fun factor: ●●○○○
Overall: 10/20

BH Easy Motion Neo Xtrem

£1,900

www.bh-emotion.co.uk

+

The only clues that the Neo Xtrem might be packing more than just pedal power are the motor mounted in the rear wheel and the stockier-than-usual downtube, within which you'll find the battery. This central positioning of the battery means the Xtrem's weight is more evenly distributed, which helps make for a responsive ride that's easily the most fun of all the bikes here.

You can chuck it around as much as you like and, even though the motor kicks in and builds quickly, you always feel in complete control. Disc brakes help in the handling stakes too and, like the Hybrid 24's, they're regenerative, so they put a little power back into the battery whenever you slow things down.

−

The LCD control unit looks very sleek, but it takes a while to fire up and its mounting bracket feels a little flimsy. Also, while the Xtrem may look more like a 'normal' bike than any of the others, it doesn't feel like one if you have to lift it! Though not quite as heavy as the other bikes featured, it's still a lot weightier than an average bike, and moving it anywhere involving stairs or narrow hallways is a chore that requires a fair bit of strength.

Design: ●●●●○
Ride: ●●●●●
Practicality: ●●●○○
Fun factor: ●●●●●
Overall: 17/20

FOCUS BEST BUY

Motor: Brushless 350W motor (limited to 250W)
Battery: Samsung Li-ion
Range: Up to 90km (55 miles)
Charging time: 3-4 hours
Gears: Shimano Alivio, 8-speed
Weight: 19.8kg

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Spencer Kelly

Robot rescue

I held my nose, tightened my grip on my waterproof camera and rolled backwards off the side of the boat into the Pacific Ocean. In the second before my body plunged into the sea, I really hoped our shoot went to plan.

Once in the water, I was doing an unintentionally good job of drowning. My hopes lay with the LA County Lifeguards' latest recruit: EMILY, the EMergency Integrated Lifesaving Lanyard. EMILY is a robot lifeguard, whose job it was to stop me from falling victim to the icy waters. A call was made to initiate the rescue, and moments later, in a scene straight out of *Robo-Baywatch*, EMILY flew into view. It could have towed me back to shore if necessary, but instead I was instructed to hold on and rest until a flesh-and-bones lifeguard came to my aid.

EMILY can reach swimmers at speeds of up to 45km/h (28mph)

This new robotic approach to lifesaving is currently being tested in a variety of situations, and will be deployed in full this summer. Some are fitted with cameras and speakers so the lifeguards can see and speak to swimmers in trouble. Others have sonar sensors, to detect underwater movements or the lack thereof, to help lifeguards assess the situation.

Eventually, a lifeguard arrived to haul me back to dry land. Treading water in the ocean is exhausting, so the help was very welcome. But just as I was about to deliver my closing line to the camera I was knocked for six by another wave – leaving me to wonder how well I would have fared without EMILY's aid, and just how many lives it could save.

Spencer Kelly is the presenter of the BBC's technology show *Click*

How to...

TECH UP YOUR CAMPING

Whether you're going to a festival or getting closer to nature this summer, you can still enjoy some of life's mod cons

CrossKase Solar 15

The solar cell fitted to this backpack powers a battery which stores enough electricity to charge up a smartphone twice over. Fill it up from the mains before you leave, then top it up with the Sun's rays while you explore the countryside. Now you just have to rely on the British weather…
crosskase.com, £139.99

Lockdown

Keep bears away from your picnic and thieves' filthy paws off your valuables with this outdoor safe. On either side of the box, a pair of ground screws burrow 20cm into the ground to keep money or gadgets safe – as long as those bears aren't carrying a spade or hacksaw.
firebox.com, £40

Biolite CampStove

While cooking your baked bean-based cuisine, this ingenious Biolite CampStove uses the heat from burning wood to power a USB port that will charge your smartphone or any other USB-powered device.
biolitestove.com, $129 (£83) plus P&P

Heimplanet Cave

If previous trips have been blighted by tents that collapse in the lightest squall, then try one that mimics one of nature's toughest structures: the diamond. Its inflatable "modular double-layer air beams" (tubes) take just a couple of minutes to blow up.
heimplanet.com, €499 (£403) plus P&P

Helio Pressure Shower

Wash nature off with a freestanding, foot pump-powered shower. It stores up to 11 litres of water – which equates to five to seven minutes of cleaning time – that's heated by leaving the Helio out in the Sun.
nemoequipment.com, price TBC

Tech Doc's App Prescription

Earthlapse

iOS, 69p

This incredibly relaxing app gives you a window seat on the ISS as it cruises over the Earth. It's not live, of course, but a collection of time-lapse videos from the space station that you can swipe through with your fingers. You can also see the time and date when each frame was taken.

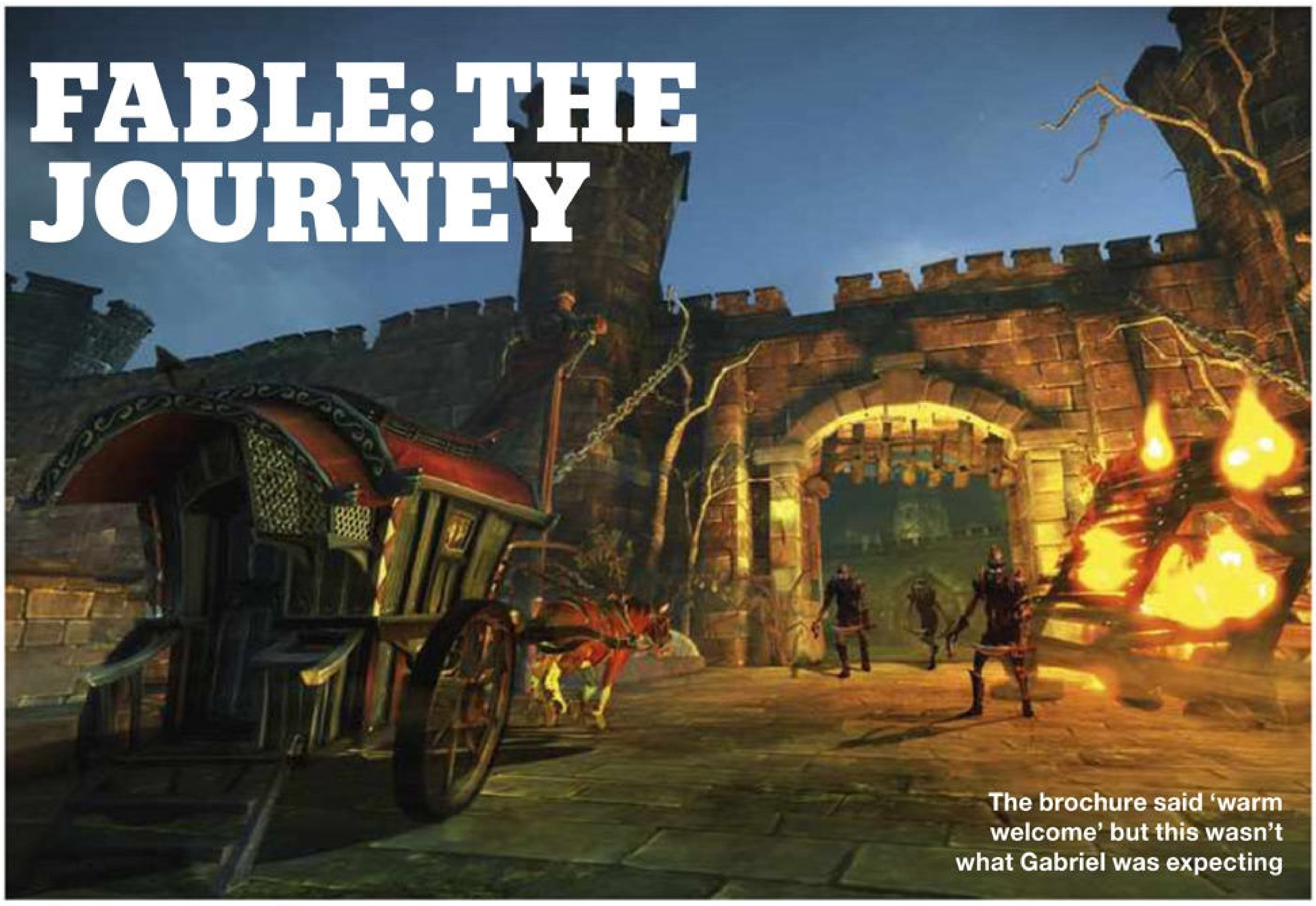
Leonardo da Vinci: Anatomy

iPad, £9.99

Leonardo is best known for his inventions and art, but he was also an anatomist. This rich interactive app explores his work on the human body through lively videos, detailed images and interactive graphics. It's a brilliant showcase of what the iPad has to offer compared to traditional books.

KIMBALL HALL

FABLE: THE JOURNEY



The brochure said 'warm welcome' but this wasn't what Gabriel was expecting

Xbox 360
Microsoft Studios
£39.99

The final entry in the bestselling *Fable* fantasy role-playing series is unlike any of the games that came before it. Where previous instalments were open-world affairs starring your created hero, *Fable: The Journey* is a linear, first-person adventure in which you take a kind of guided tour of Albion, the series' fantasy setting based loosely on medieval Britain, on foot and in a horse-drawn cart. And instead of controlling a player-made hero whose appearance you've finely tuned – right down to the shape of their eyebrows – you play as plucky gypsy youth Gabriel.

More significantly, *Fable: The Journey* is played purely through Kinect, the Xbox 360's motion-control system, usually known for the more obvious fitness games and party titles. Instead, this is a story-led, lengthy (nine or 10 hours long, say the developers) adventure – potentially the first game that fully embraces Microsoft's motion-control system. When riding your horse, you steer, gee up and slow down by mimicking rein operations, and you cast magical spells by pointing and flicking. Treasure chests are flung open with the expected gesture, and when your horse – a glossy shire named Seren – is stuck with enemy arrows, you must pull them free.

The success of *Fable: The Journey* is far from assured. But although it may disappoint its fervent fans, it may find a new audience among young, energetic and open-minded Kinect players. It's definitely worth keeping an eye out for.

Once a big star, these days Skeletor has to eke out a living playing bit parts

ALSO OUT

SLEEPING DOGS

PC, PS3, X360
Square Enix
£39.99

An urban, open-world action game, *Sleeping Dogs* casts you as an undercover cop in Hong Kong, making it something like a *Grand Theft Auto* game, albeit without the blockbuster slickness of Rockstar's series. It's also heavily inspired by the style and violence of Hong Kong action cinema, with brutal execution moves that make weapons of the scenery.

BORDERLANDS 2

PC, PS3, X360
Gearbox
£39.99

The sequel to Gearbox's unique 'role-playing shooter', *Borderlands 2* blends first-person shooter action, moreish role-playing game elements and a keen sense of humour, all set in a sci-fi desert wasteland. The eye-pleasing art style returns as well – all popping colour and comic book outlines. For best results, enlist three friends and go to work in the four-player co-operative mode.

Jane Douglas

Auteurs wanted

Peter Molyneux is a celebrated British game designer with a proven track record, counting titles such as *Fable*, *Populous* and *Dungeon Keeper* among his greatest hits. He's also a master showman, notorious for talking up attention-grabbing, out-there features that fail to materialise in finished games. The best remembered among these involved an acorn that, he speculated, would incidentally fall from a tree in his game world and over time grow into an oak, populating the virtual world with ever-changing forests. The hallowed woods never materialised.

Whether or not Molyneux is just a dreamer, he is unmistakably an auteur: an ambitious and individualistic visionary familiar enough in filmmaking, but hardly encountered in video games. Unfortunately, big-budget games are the works of enormous, specialised teams – not the ideal arrangement for channelling a lone talent's creative vision.

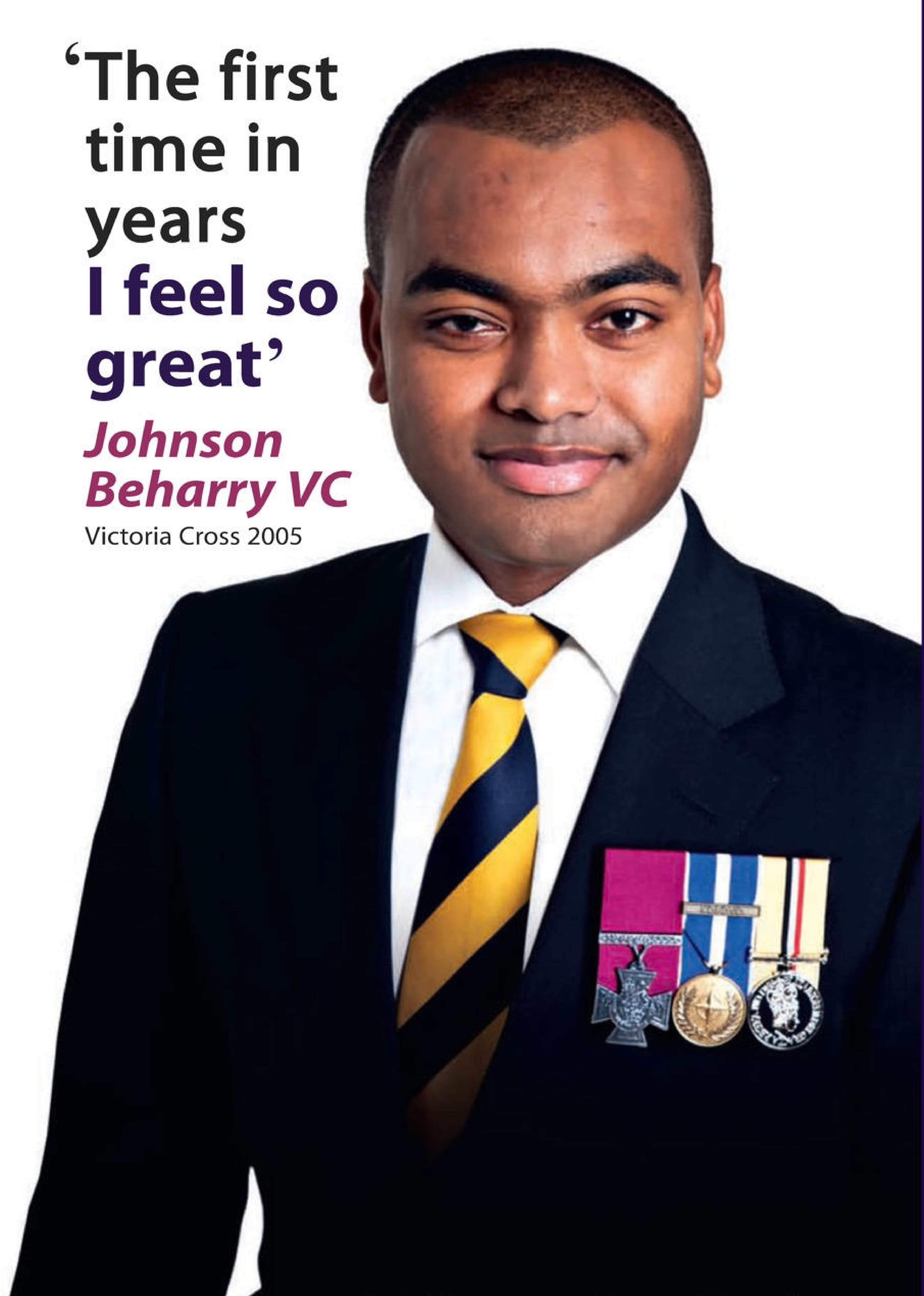
Big ideas: Peter Molyneux

As a corollary, smaller budget games – often independently made – have been the ideal medium for a game-maker with auteur-like leanings. Unique, low-cost endeavours such as the recent space-warping *Fez* or, looking a bit further back, the time-bending *Braid* are inspiring adventures that have enjoyed reasonable success.

Now, in the wake of an uninspiring E3 – the convention where future games and consoles are launched – full of same-y mainstream games, perhaps the individualist auteur is just what the doctor ordered. The future of video games needs more people like Peter Molyneux if it's going to continue to prosper.

Jane Douglas is section editor of GameSpot UK

GAMESPRESS X4, REX

‘The first time in years **I feel so great**’

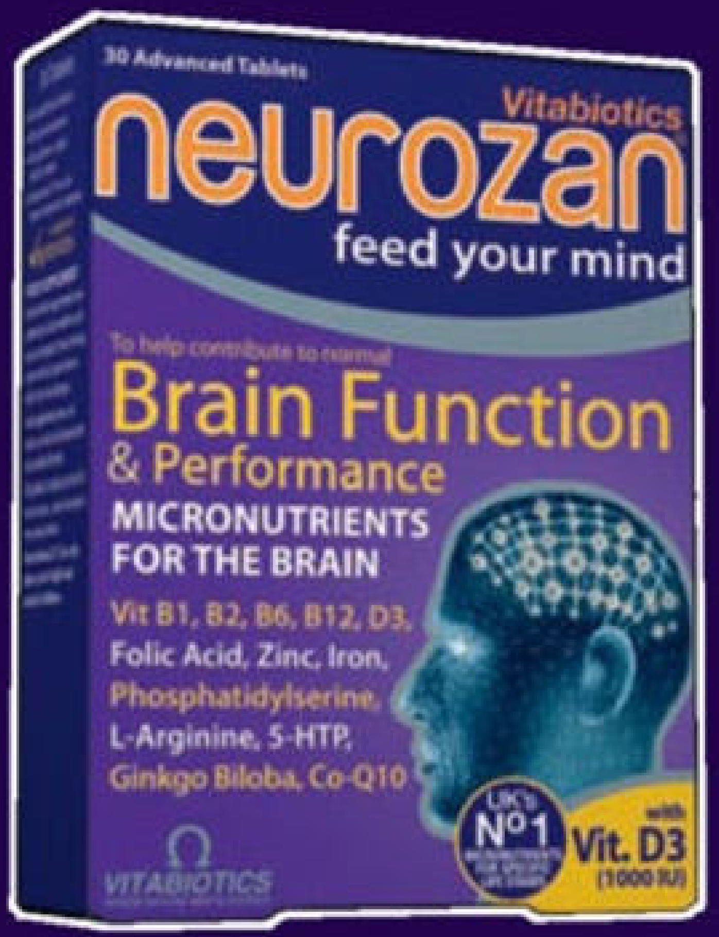
Johnson Beharry VC
Victoria Cross 2005

*‘I would like to express my gratitude to Vitabiotics for their supplements. **Neurozan®** has helped to maintain my brain function, and **Wellman®** has really helped to maintain my overall health, vitality and performance. I even managed to compete in the highly strenuous **Dancing on Ice** due to the help from Vitabiotics.’*

JBeharry VC
Johnson Beharry VC

In Tribute to Great Heroism

Johnson Beharry is one of a distinguished few to receive the Victoria Cross, Britain’s highest award for gallantry and the ultimate symbol of sacrifice and courage. Johnson Beharry carried out two individual acts of great heroism by which he saved the lives of his comrades... at great personal risk to himself (one leading to him sustaining very serious injuries). Beharry displayed repeated extreme gallantry and unquestioned valour.



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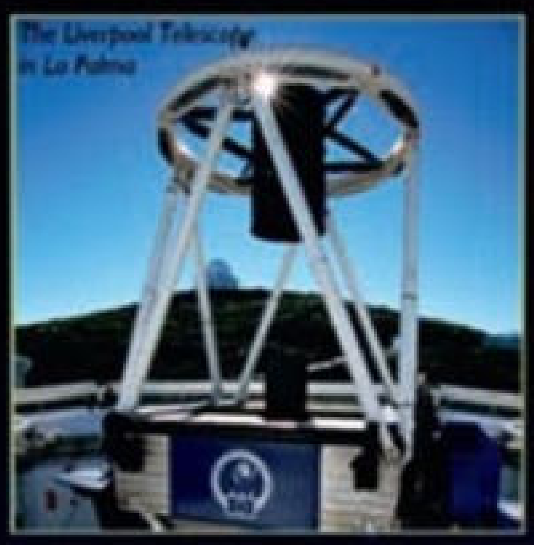
Astronomy by Distance Learning



The Liverpool Telescope in La Palma

A Liverpool Telescope image of M16

liverpool JMU

- Exploring The Universe
- Astronomy for Teaching
- The Science of Science Fiction
- Planetary Geology
- The Universe Through a Small Telescope
- Galaxies
- Stars
- The Universe Through a Large Telescope
- Planetary Atmospheres
- Modern Cosmology
- Gamma Ray Bursts
- Exoplanets

Background Image: A Liverpool Telescope image of Comet C200217

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Bill Thompson

Your data in their hands

When a certain NHS Trust upgraded its computers a couple of years ago, it failed to ensure that the company tasked with disposing of the Trust's hard drives did the job properly. As a result, over 200 of them found their way onto eBay – exposing the confidential patient information of tens of thousands of patients.

It isn't just medical records that leak out. In 2007, the financial details of seven million families who receive child benefit were "lost in the post" between Revenue & Customs and the National Audit Office. That same year, hackers acquired details of over 45 million cards used by customers of US retailer TJX, which owns TK Maxx. And in June 2012, professional networking site LinkedIn had to admit that almost seven million user passwords had been leaked onto the internet.

The breaches continue: an online search for 'data breach' will reveal a catalogue of embarrassed executives apologising to their users or customers this year for having been careless with their personal information. This all has a real cost, both to the people affected who may have to change credit cards or bank details, suffer from fraud or have their personal lives exposed online, and to the firms themselves. Every year, the Ponemon Institute produces a study for computer security firm PGP into the cost of data breaches, which shows that each costs millions of pounds.

But this hasn't slowed how much information we share. The Government, private companies, schools, hospitals and seemingly everyone else expect us to trust the security systems they've put in place, whether we're buying groceries, booking an appointment with a GP or applying for a passport or bank account. We do this even though we know that no computer system can be truly secure, and even though the evidence of carelessness or simple stupidity on the part of the 'data controllers' continues to pile up.

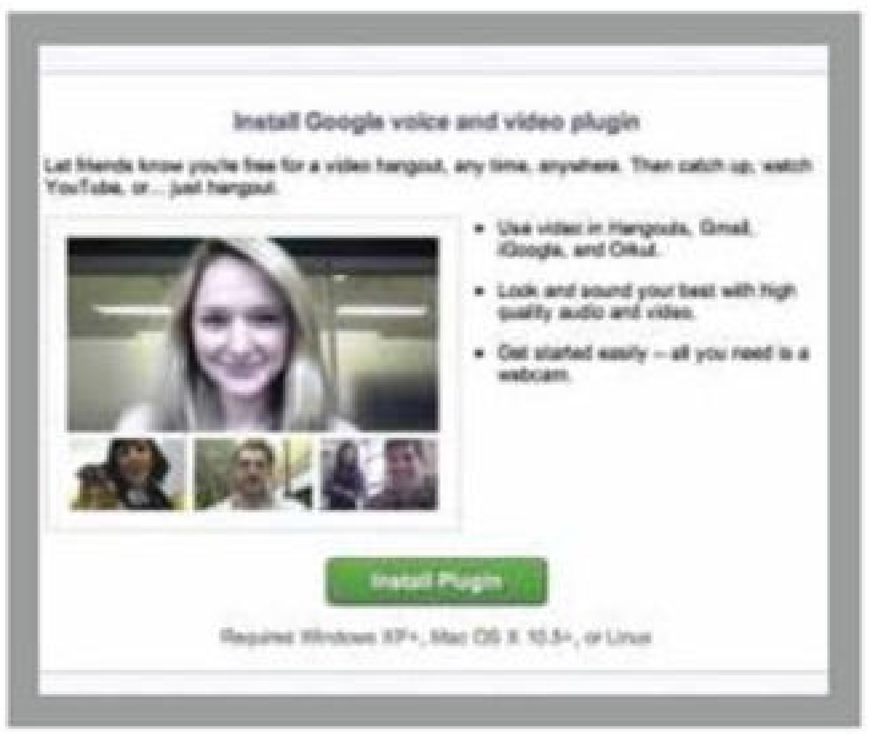
New laws are passed, and the Information Commissioner's Office hands out the occasional fine, but the reality is that we – myself included – do not seem to care enough to call for fundamental changes either to the law or to security practices. Perhaps we have all done the calculations and decided that the risk is worth it, just as we decide the benefits of travel offset the risks of driving.

I think it's more likely, though, that we have collectively crossed our fingers and are hoping it will be okay. We may be in for a shock.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

WEB HACKS

Videoconferencing with Google Hangouts



Install Google voice and video plugin

Let friends know you're free for a video hangout, any time, anywhere. Then catch up, watch YouTube, or... just hangout.

- Use video in Hangouts, Gmail, iGoogle, and Orkut.
- Look and sound your best with high quality audio and video.
- Get started easily – all you need is a webcam.

Requires Windows XP+, Mac OS X 10.5+, or Linux

Why? We seem to be moving into an era when video calls are required practice, especially for business meetings where not everyone can be present.

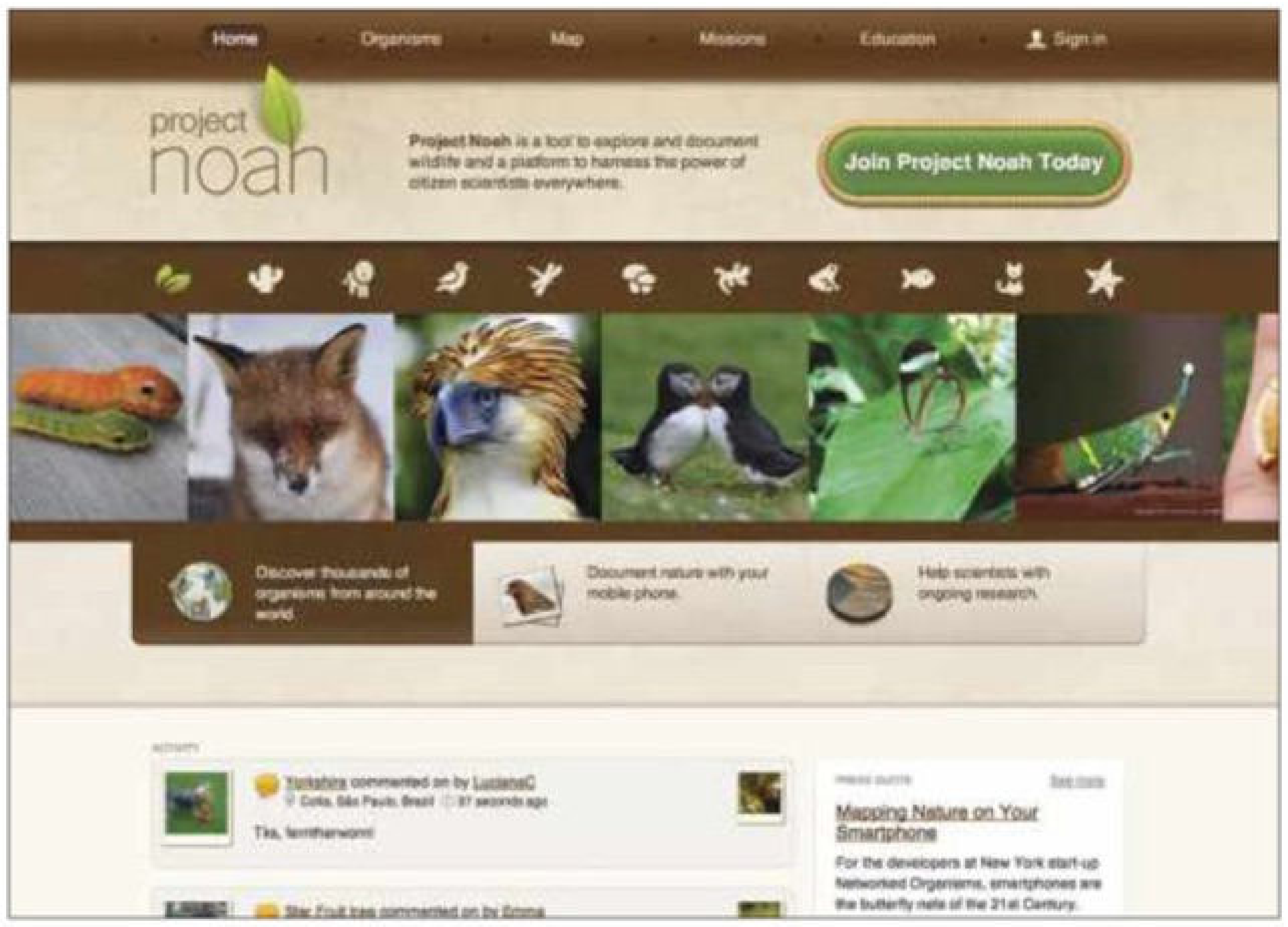
What? Hangouts offer simple video chat with up to nine people at once. It's well integrated with other Google services, so you can share screens and work collaboratively while video calling. If you've got the Google+ app on your Android phone or iPhone you can take part in hangouts on the move, and some news organisations are experimenting with 'public hangouts'.

How? Hangouts are part of Google+, so you and the people you're calling will need a Google account. This isn't too much of a hurdle, since Google is forcing this on anyone who wants to do anything other than a basic search on their site. Go to the address below and install the relevant browser plug-in. Select 'Hangout' and then 'Start a hangout' from the menu, and choose the Google contacts you want to invite.

Where? j.mp/GHangouts

Project Noah

projectnoah.org



Project Noah is a tool to explore and document wildlife and a platform to harness the power of citizen scientists everywhere.

Discover thousands of organisms from around the world.

Document nature with your mobile phone.

Help scientists with ongoing research.

Mapping Nature on Your Smartphone

For the developers at New York start-up Networked Organisms, smartphones are the butterfly nets of the 21st Century.

If you care about the growing threats to Earth's biodiversity but don't have the time or energy to build an ark, then this site should appeal. Project Noah asks members to upload photographs of wildlife, which can be placed on an interactive map, and encourages you to go on 'missions', such as documenting dragonflies or finding all the species in your school playground. There are also resources for classroom use, and teachers can join as a group to make it easier to manage.

The site is easy to use, having been designed to make it simple for as many people as possible to take part. You can sign up using an existing social media account, and access Project Noah through a smartphone app. It's a neat idea, nicely executed, and a worthwhile addition to the list of online 'citizen science' projects.

RIBAPix

ribapix.com

The Royal Institute of British Architects has an amazing library of architectural images. Easy to search and browse, the online collection is organised around themes such as monuments and memorials, power stations, modern French architecture or post-war housing. Low-resolution images can be downloaded for private use or teaching, or you can pay for high-resolution versions without a watermark if you want to turn them into a print.

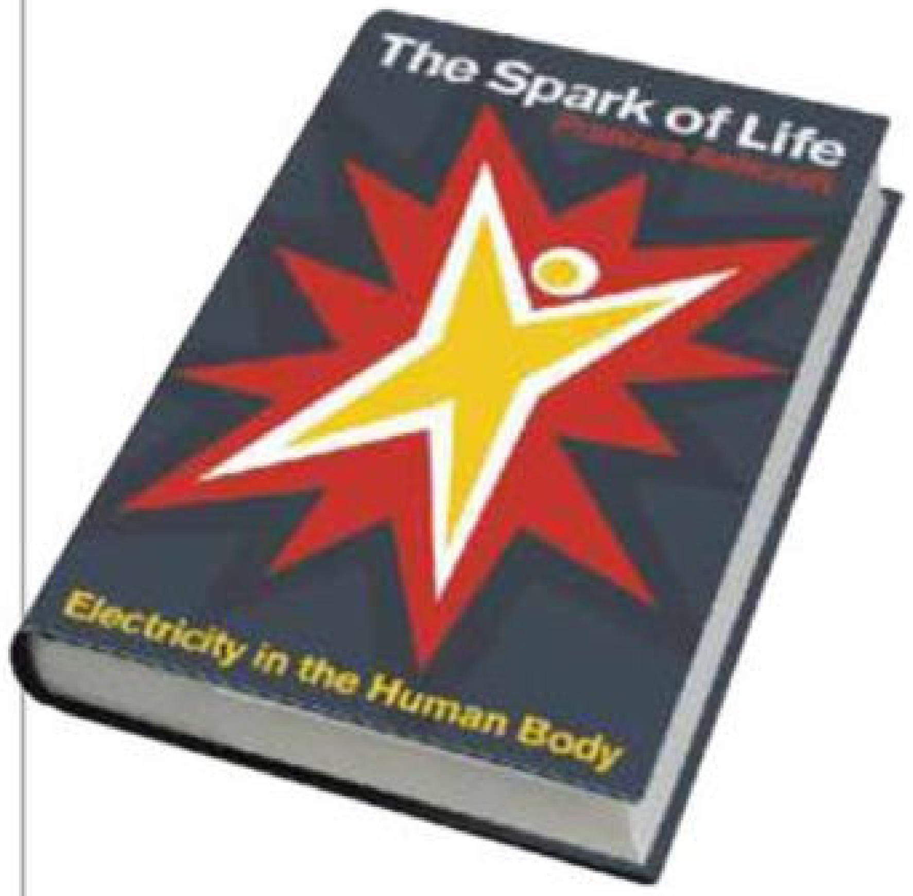
Thingiverse

thingiverse.com

3D printers which build up solid objects from layers of plastic gloop, or metal in more expensive versions, have gone from science fiction to a common feature in laboratories in just a couple of years. Thingiverse is a great website that lets designers upload and share their models, from a 3D surface map of Mars to model robots. If you're lucky enough to have access to a printer, you can print them yourself; otherwise, you'll just have to daydream.

The Spark Of Life

An enthusiastic book on the importance of electricity to biology, says **Prof Steven Rose**



Electricity In The Human Body
Frances Ashcroft
Allen Lane, £25
(hbk/ebook, 352pp)

When Mary Shelley described how Victor Frankenstein brings his monster to life through the power of electricity, her famous novel was drawing on the very latest theories of early 19th century science. Researchers were beginning to believe that 'animal electricity' was the mechanism through which nerves and muscles worked – indeed, the spark of life. It took a further century and a half, however, before those mechanisms could be understood in the language of physics and chemistry.

The clue lies in the lipid membrane that surrounds and encloses all the cells of the body – a membrane that keeps some molecules out and others in. Inside the cell there are relatively high concentrations of electrically-charged potassium ions; outside, the fluid that bathes all cells is high in sodium, pretty much like seawater. This asymmetry means there's a tiny electrochemical gradient across the membrane. But the membrane isn't quite impermeable – it's punctuated with miniature channels made of protein, channels which (depending on their chemical state at any moment) are just the right shape to permit the passage of electrically charged ions such as sodium and potassium.

Frances Ashcroft, a professor of physiology at Oxford University, has spent her life trying to understand just how these ion channels work. *The Spark Of Life* conveys all the passion of a scientist in love with her subject and wanting to share her enthusiasm with others.

As she explains, it's the flux of ions through the channels that underlies nerve conduction and muscle contraction – and much more besides, from the mating dance of sperm and egg to photosynthesis in plants. Ashcroft carries her readers along through a mix of history, anecdote and personal reminiscence, making light work of even the densest technicalities. The result is a book that is ideal for any budding biologist – and anyone else with a spark of interest in the spark of life.

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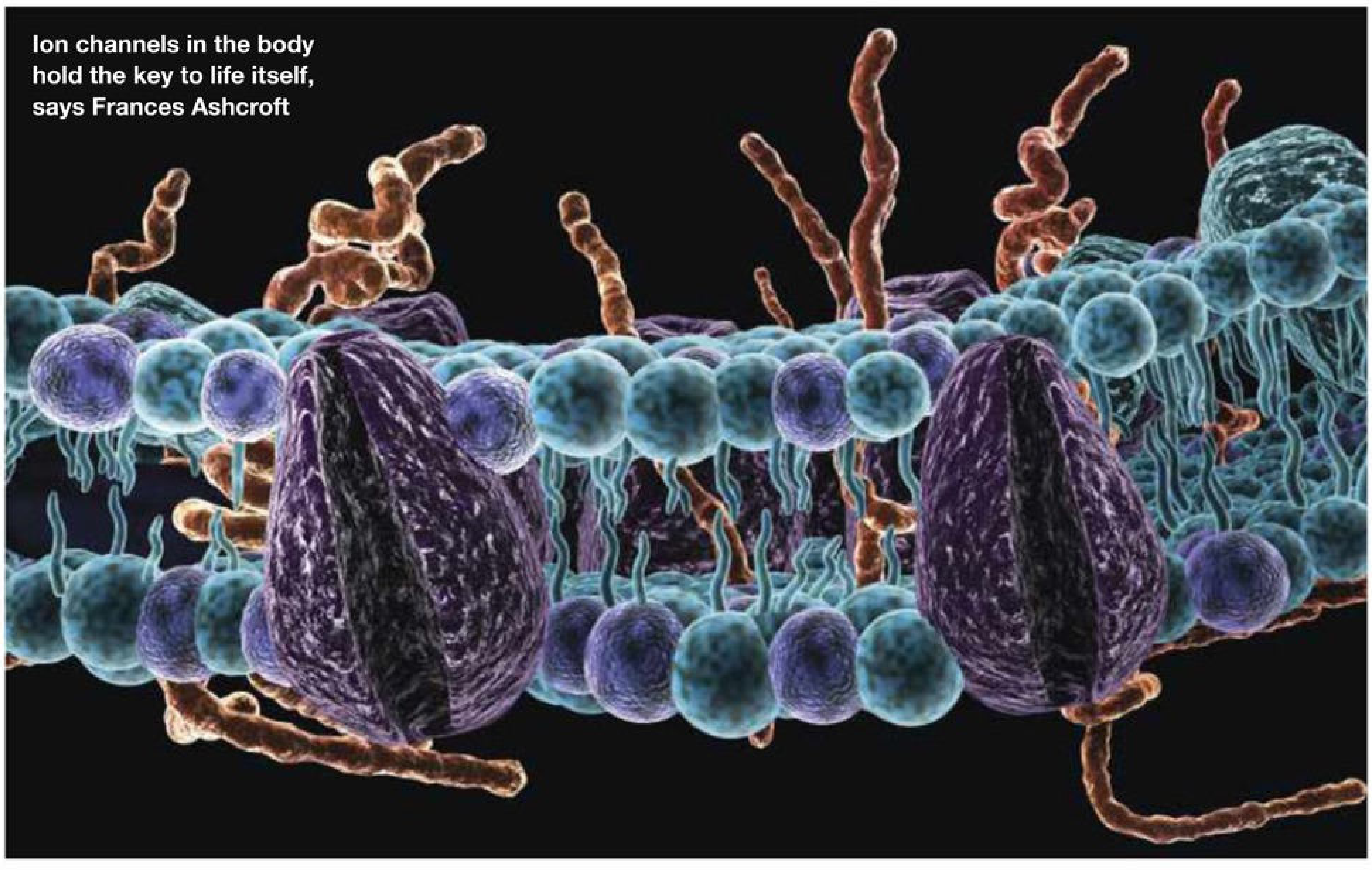
***Neurobiologist Steven Rose is co-author of* Genes, Cells And Brains**



Ion channels in the body hold the key to life itself, says Frances Ashcroft

SCIENCE PHOTO LIBRARY

Author Q&A

Frances Ashcroft on *The Spark Of Life*

Why did you decide to write this book?

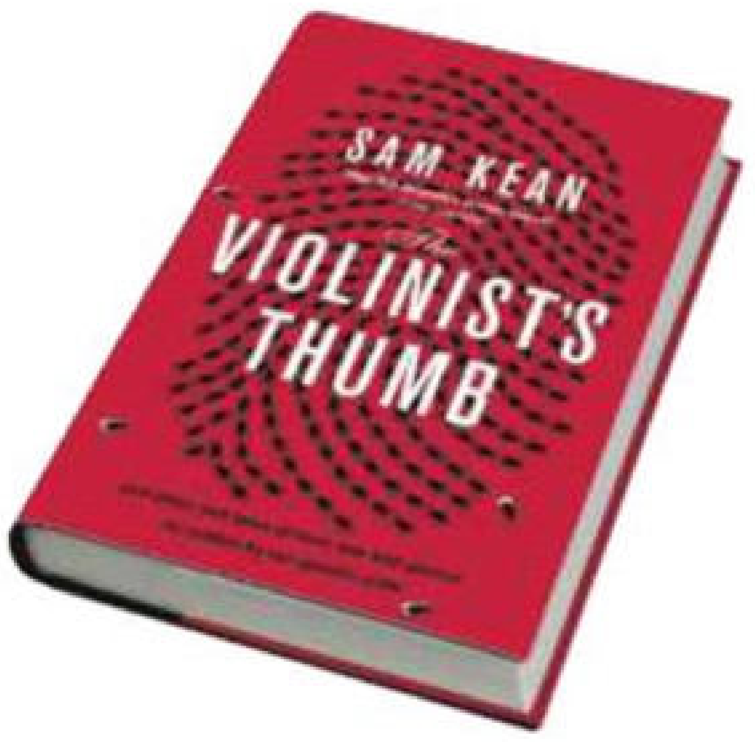
Everything that you do is down to ion channels, which are tiny microscopic pores found in the membrane that surrounds every cell in your body. Ion channels are incredibly important but nobody's ever heard of them, so I thought it would be fun to tell their story. They're responsible for impulses, the electrical events that drive your ability to think, see and move. But those pores do much more than just generate electrical impulses. When they go wrong, diseases such as cystic fibrosis happen.

What surprised you most?

There's a marvellous story from 401BC about the Ancient Greek commander Xenophon, who described being in an area of the Black Sea where 'mad honey' is produced. Many toxins work by opening or closing particular ion channels. One toxin is found in the nectar of rhododendrons, which is collected by bees and made into 'mad honey': if you eat this, it makes you extremely ill because the toxin blocks the impulses in your nerve fibres. Xenophon's soldiers gorged themselves on the honey and soon they were all lying on the ground, vomiting. The next day, they were OK. When they were invaded by the Romans, the Greeks decided this might make an effective biological warfare agent. So they strewed mad honey in front of the troops, who ate it and were incapacitated – and more easily decapitated.

Which part of the book was most challenging?

Probably chapter two, where I introduce electricity. It's necessary in a book like this to explain current, electric potential, volt, amp, electrical resistance and what ground is. That was the most tricky bit to write, where it's not possible to tell so many stories.



The Violinist's Thumb

And Other Lost Tales Of Love, War And Genius, As Written By Our Genetic Code
Sam Kean
Doubleday, £20
(hbk, 320pp)

Embedded in human DNA is the history of our evolutionary adventure. All you need is a little guidance on how to read it. Sam Kean proves an entertaining guide to this saga in which the hero, the human genome, is fortunate to survive the journey. Far from the simple construction taught in biology classes, we learn that our genome is a mixture of vertebrate, bacterial and even viral inheritance.

What might otherwise have proved boringly technical is leavened by Kean's gift for simplifying complex information into reader-friendly language, coupled with a never-ending stream of comic asides. The thumb in the title is that of 19th century Italian violinist Niccolò Paganini, whose musical dexterity may well have been due to a genetic condition, though he made the most of rumours that attributed his talent to the work of the Devil.

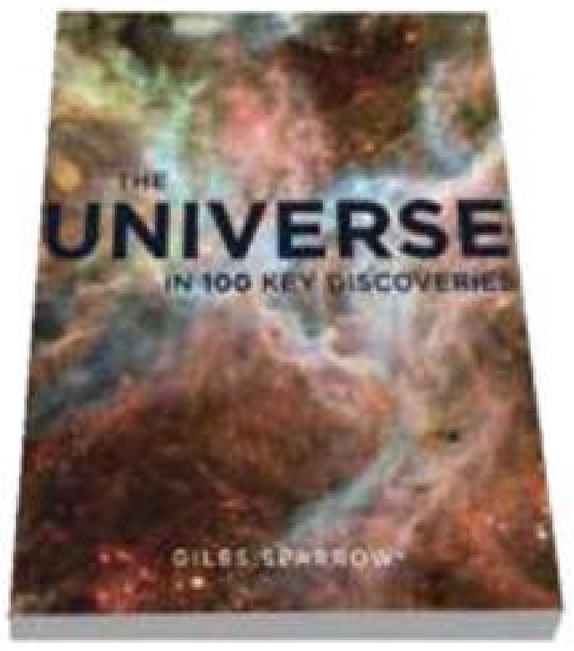
This book has a pleasantly surprising number of twists and turns. I particularly liked the story of Gregor Mendel – the cigar-smoking abbot who discovered genes – and his showdown with the local sheriff over taxes, and the tragedy of the hapless Willem Barentsz. On searching for a passage through polar ice, he discovered that the up-to-then mythical polar bears were ravenously real.

●●●●○

***Dr Frank Ryan is a biologist and the author of* Virolution**

The Universe

In 100 Key Discoveries
Giles Sparrow
Quercus, £19.99
(pbk, 416pp)



Giles Sparrow brings us the top 100 discoveries in the history of astronomy and space exploration. We're transported from the very origins of the Universe, in a piece about the realisation that the entire cosmos erupted out of a fearsomely hot singularity, to the discovery of the mysterious dark energy that pervades space and may rip the Universe apart. In between, he covers plenty of landmark findings. Each of the key concepts is covered in two or three pages, the perfect length to give you a feel for why each of the discoveries is so important without getting too bogged down in detail.

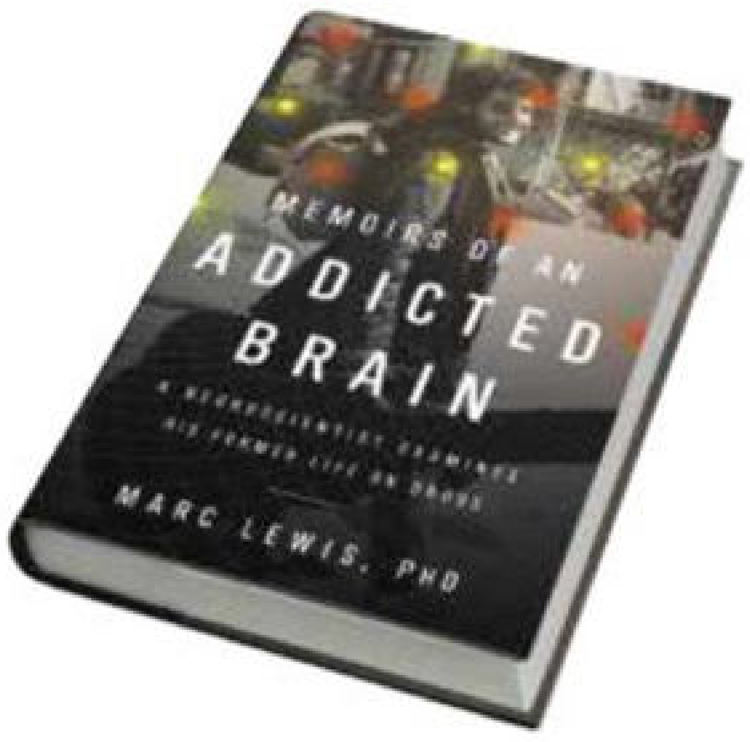
As for the pictures, *The Universe* has all the beauty of a coffee table book, with every entry accompanied by gorgeous photography. Galactic mergers, vibrant nebulae and planetary vistas are all present and correct. One of my favourites was the mini-essay on the revelation in the 16th century that the Earth wasn't in the centre of everything after all – a well-known story that's retold refreshingly here. Other highlights include articles on the discoveries of gamma-ray bursters and supermassive black holes. My tip: ignore the contents page and just flip through until something catches your eye. You never know what you might find out.

●●●●●

***Lewis Dartnell is an astrobiologist and author of* Life In The Universe**

Memoirs Of An Addicted Brain

A Neuroscientist Examines His Former Life On Drugs
Marc Lewis
Public Affairs, £17.99
(hbk, 336pp)



Memoirs Of An Addicted Brain by neuroscientist Marc Lewis is a strange and unsettling book. In it, the author traces the course of his early life, from unhappy teenager to life as a junkie and convicted criminal. The book starts in a boarding school where, bullied and low in self-esteem, the teenage Marc gets high on cough mixture and marijuana. He's then off to Berkeley in California, where he sinks deep into the drug culture of the late 1960s.

LSD, PCP, opium, heroin... you name it, Marc Lewis seems to have eaten, smoked or injected it, often in large amounts. There was almost nothing he wouldn't take. Doing research on rats, Marc comes across a bottle of morphine sulphate in an old fridge that was intended for a long-forgotten experiment. Without much hesitation he injects himself with it.

But while the narrative of Marc's life is a real page-turner, what makes this such an interesting and unusual book is that it also contains detailed descriptions of the neuro-chemical changes that are going on inside Marc's brain as he takes the different drugs, and later as he wrestles to come off them. After reading this book, I felt that I understood for the first time what addiction is like at both the personal and the chemical level.

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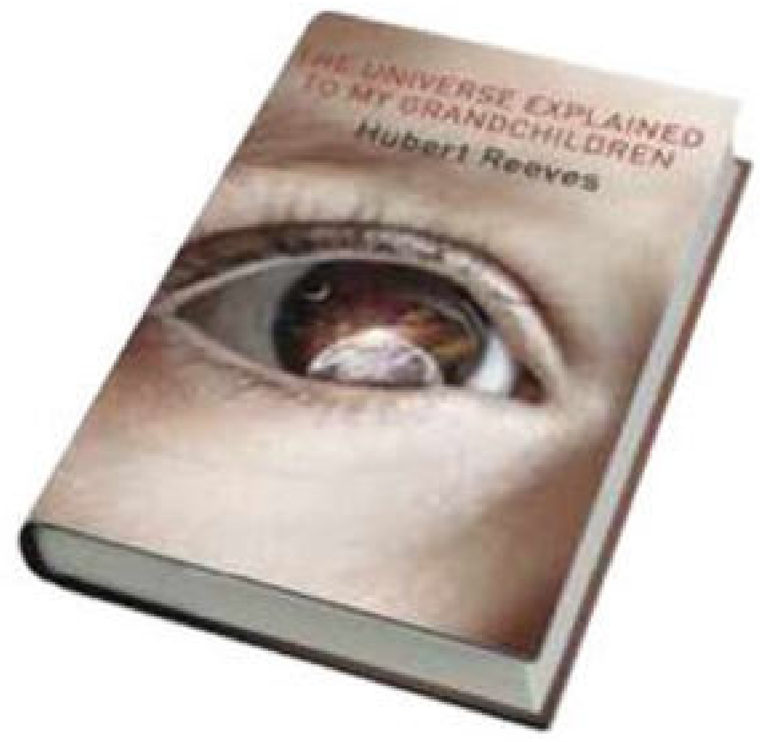
Dr Michael Mosley is a writer and BBC science presenter



The Universe Explained To My Grandchildren

Hubert Reeves
Salammbo Press, £6
(hbk, 124pp)

Hubert Reeves is one of France's foremost astrophysicists and science popularisers. He also has eight grandchildren, who apparently often quiz him about his knowledge of the Universe. So one day he decided to put together a collection of their queries interleaved with his answers, to share with the world at large.

The Universe Explained To My Grandchildren is a truly delightful book. Extremely short and written in simple but engaging language, it nonetheless manages to convey some very profound ideas about the Universe, its origin and fate, and our place in it. For anyone with even a passing interest in astrophysics, it's a perfect, painless introduction to the subject.

I particularly liked Reeves' discussion of the 'emergence' of ever more complex phenomena in the Universe. Just as new possibilities arise when letters combine into words, words into sentences and so on, new possibilities arise as the Universe's building blocks – from quarks to human beings – come together to create ever more novelty.

As Reeves says, "For you to be conscious of your own existence and that of the world around you, a hundred billion billion billion quarks and electrons, woven together in a structure of unimaginable complexity, have had to play their individual roles." Quite a thought.

●●●●●

Marcus Chown is a cosmologist, science writer and broadcaster

AUGUST TO-DO LIST

The essential guide to the month ahead

20 JULY -26 OCTOBER

This iron limb is thought to have belonged to a 16th century German knight

Superhuman

Science isn't just for the betterment of humanity, you know – it's also been pretty helpful in making humans a bit easier on the eye.

From Egyptian prosthetic toes to modern lipstick, from test-tube babies to Viagra, this exhibition takes a fun look at how the human body has been aided and enhanced by science throughout the centuries. It doesn't stop there either, looking forward to how cutting-edge science is paving the way for a future of cognitive enhancements and nano-robots that'll make us more than human.

Wellcome Collection, London, free, www.wellcomecollection.org

3 -9 AUGUST

Revenge Of The Electric Car

With fuel prices rocketing, there's a race on to build the ultimate consumer electric car. This documentary goes behind the scenes at major manufacturers as they battle with the economy, the competition and public expectations. Narrated by Tim Robbins, the film is packed with characters, including dotcom billionaire and Tesla Motors boss Elon Musk, cigar-puffing General Motors executive Bob Lutz and backyard inventor Greg 'Gadget' Abbot, who hopes to find a way to convert gas-guzzlers into electric-powered cars.

Chapter, Cardiff, £6.60. Further screeings to be announced, so keep an eye on www.revengeoftheelectriccar.co.uk for details

General Motors bosses unveil the hybrid Chevrolet Volt

Radio 4's Helen Keen will be peering into the future

1 -26 AUGUST

Helen Keen: Robot Woman Of Tomorrow

Award-winning comedian and creator of BBC Radio 4's *It Is Rocket Science* Helen Keen returns with an esoteric mix of science fiction and shadow puppetry. Her new show debuts at the Edinburgh Fringe, where she plans to transport the audience to the "tinfoil-y world of the future". A regular on *Infinite Monkey Cage*, you won't want to miss Helen's quirky and original take on where mankind is heading.

Pleasance Courtyard, Edinburgh Festival Fringe, 3.30pm, £9.50, www.edfringe.com/whats-on

3 AUGUST

From Corpses To Collections

Ever wondered how dead animals are prepared for display in a museum? No, we haven't lately either. But if you are curious how the whale that found itself stranded in the Thames nearly four years ago ended up in the Natural History Museum's collection, then this talk will have the answers. It's definitely not one for the squeamish, though.

Natural History Museum, London, 12.30pm and 2.30pm, free, www.nhm.ac.uk/nature-live

DOGWOOF, SCIENCE MUSEUM, MOSI, AND FESTIVAL/ARTS CATALYST, SONY PICTURES, SCIENCE PHOTO LIBRARY

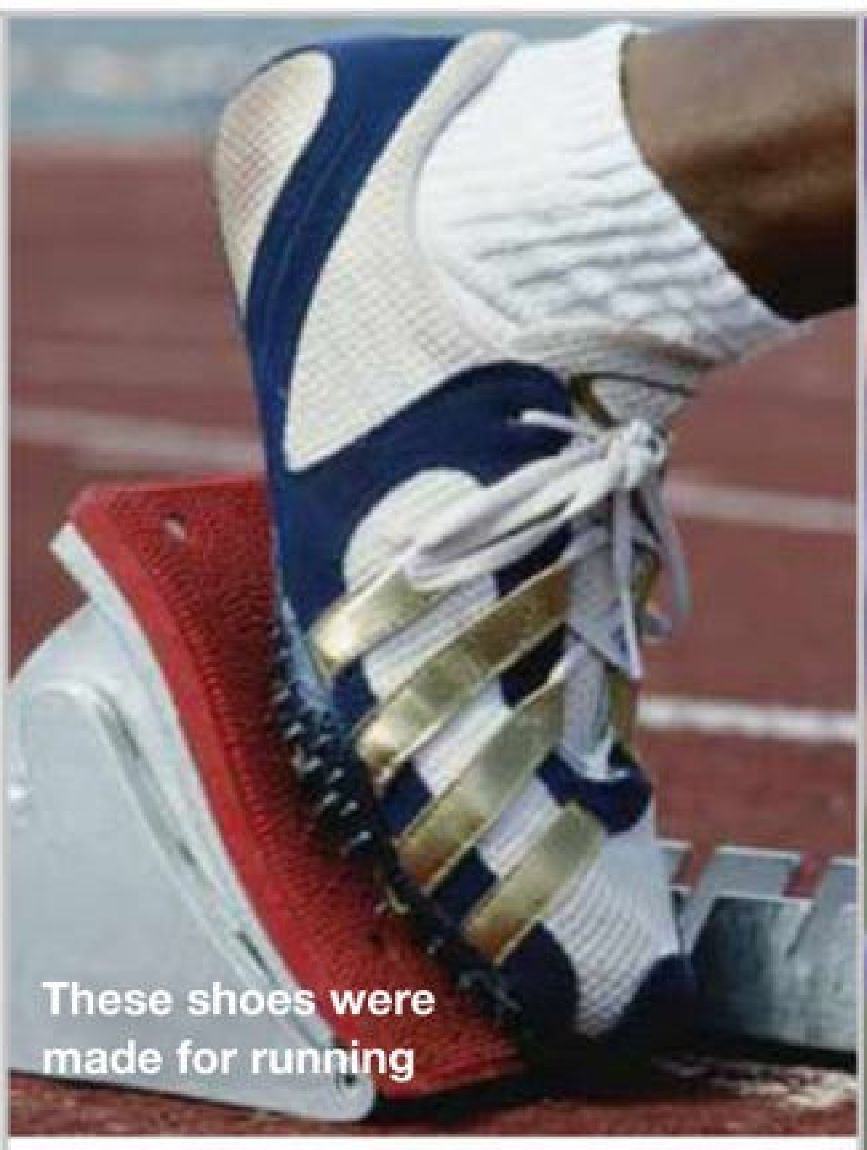
4-5 & 11-12 AUGUST

Transport Festival

If you love planes, trains and automobiles, then you're going to love this traffic jam of classics at Manchester's transport festival, running over the first two weekends in August. Everything from London buses to early cars will make a rare outing from their vacuum-sealed storage sheds in order to parade the festival grounds.

Museum Of Science And Industry, Manchester, free, www.mosi.org.uk

Trainspotting made easy at MOSI


These shoes were made for running

14 -17 AUG

Super Speedy Sprint

The likes of Usain Bolt have their running shoes specially made for them. That's beyond most people's budgets, but you can see what tailor-made shoes would feel like by taking part in experiments with a team from Loughborough University – and feel the difference in your own running performance.

Science Museum, London, 11am-4pm, free, www.sciencemuseum.org.uk

UNTIL 18 AUGUST

LAST CHANCE TO SEE

Busy Bees, Bristly Beetles And Other Pollinators

If you think flowers are just there to look pretty, think again. Discover the complex array of tricks that flowers use to attract insects on this self-guided trail through the Botanic Gardens' tropical, desert and temperate glasshouses. Then drop in for some hands-on activities in the Glass Class, or go on a Bee Walk in the grounds.

St Andrews Botanic Gardens, St Andrews, Fife, £2/£1, www.st-andrews-botanic.org

29 AUGUST

Total Recall

This reimagining of the Philip K Dick short story sees Colin Farrell, not Arnie, struggling to discover which memories are his and which have been implanted. There'll be less Martians in this remake, which focuses on the power struggle between the nation states of Euroamerica and New Shanghai. But there will be plenty of flying cars, holographic faces and futuristic weapons, plus Dick's trademark themes of identity and deception.

In cinemas from 29 August

30 AUGUST -2 SEPTEMBER

M-Blem: The Train Project

This exhibition takes a mischievous look at our reliance on the car, as Helen Evans and Heiko Hansen (collectively known as HeHe) propose an alternate future where personal trains replace the car as the main means of autonomous transport. If you've ever been on a crowded train at rush hour, you'll appreciate their vision of a locomotive for one.

Museum Of Science And Industry, Manchester, free, www.mosi.org.uk

Could personal trains be the future of transport?

TV & RADIO

The month's top science programmes

Beat The Ancestors

Channel 5
August TBC

Ancient technology was all very impressive in its way, but those Romans, Saxons and other historical dudes weren't a patch on today's engineers, right?

We'll find out. In this series, Dick Strawbridge sets a team loose rebuilding a Byzantine fire boat, a medieval 'machine gun' and other technological marvels of the past. While the engineers use original blueprints, authentic materials and their own 21st century skills to recreate some of the biggest machines of the past, Dick checks out the history using CGI and field trips. For example, did you know that our Gothic cathedrals were built using wooden cranes powered by treadmills? When Dick visits Canterbury Cathedral, he discovers that not only was a leftover crane built into the roof, it was used for repairs as recently as the 1970s.

After only a few days' building time, the engineering team will test their constructions to see if they're able to improve on the wisdom of the ancestors. Will Roman War Machine Mk 2 be better than the ones they used to invade the British Isles and conquer Carthage? We'll find out.

Dick Strawbridge investigates past technologies

Pyros

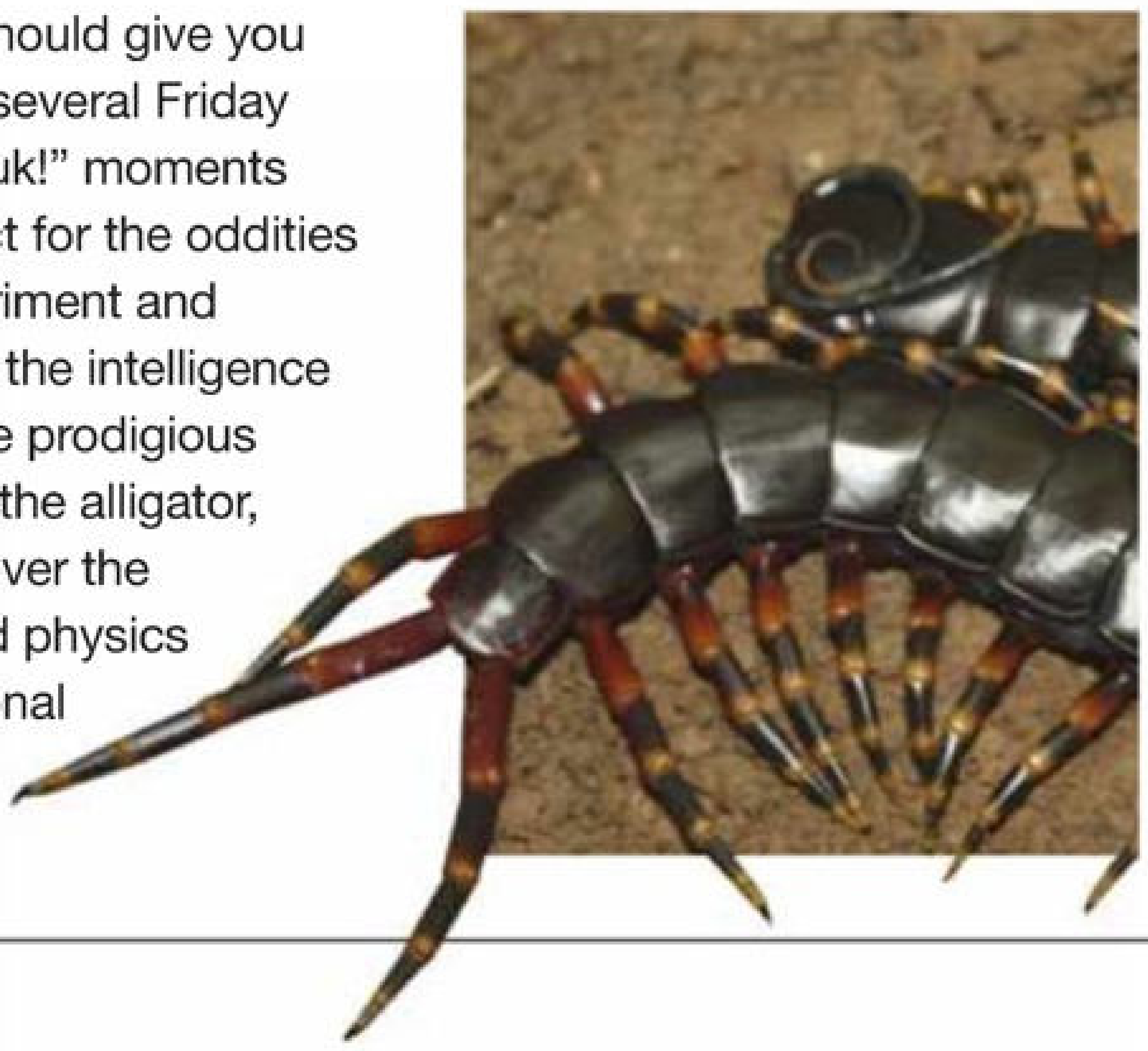
Discovery Science
Starts 27 August, 10pm

Cross science with a travelling circus, with a bit of pyromania thrown in, and you get a professional fireworks display team. This eight-part series follows Fiatlux Ampleman, sadly not a person but the company behind some of the world's most spectacular displays. Designing and delivering a fireworks display demands a combination of explosive chemicals, technological mastery and an artistic eye for what's going to make a crowd of thousands go "Ooh!" and "Aah!" at the right moments. Teams work outdoors, in all weathers, with material that could blow parts of your body into next week – even setting it off requires hundreds of metres of control wire and a computer that controls which rockets fire when. We're not talking sparklers – this is dangerous work!

Super Freaks Of Nature

Quest
Starts 23 August, 9pm

This two-part series should give you enough pub facts for several Friday nights, a couple of "Yuk!" moments and a renewed respect for the oddities of nature. Using experiment and investigation to probe the intelligence of the octopus and the prodigious night-hunting skills of the alligator, the programmes uncover the biology, chemistry and physics behind these exceptional creatures. Also: daredevil goats.



THINKSTOCK X3, RUTH HARRIES, NATIONAL GEOGRAPHIC CHANNEL X2, DISCOVERY NETWORK X2

Radio

Science Of Paralympics

BBC World Service
Starts 20 August

In the week that leads up to the Paralympic Games, four programmes look at the science behind the sports and the competitors. Engineering achievements like Oscar Pistorius' running legs could soon outstrip the capabilities of the unaided human body. But the ability of the human mind and body to overcome its own physical limitations is even more impressive. How do the elite sports performers of the Games go for gold?

The Culture Of Gaming

BBC World Service
Starts 11 August
Radio 4 Extra
Starts 16 July, 6.30pm

For a medium that didn't exist 50 years ago, computer games have quickly come to dominate our culture. Lara Croft and the brothers Mario are as familiar as Indiana Jones or Mickey Mouse. Older forms like cinema and even books are influenced by gaming, and for many people it's the cultural form they use most. In these two programmes, Aleks Krotoski investigates the impact of gaming: from fine art to the way we tell stories.

The Wallace & Gromit Prom

BBC Radio 3
29 July, 3.30pm

Live from the Royal Albert Hall, the programme includes Wallace's commission *My Concerto In Ee, Lad*. Aimed at a family audience, the music includes a live orchestral soundtrack to *A Matter Of Loaf And Death*, so look out for the television screening, too. But if you have any affection for inventors, engineering or technology, one piece alone – John Adams' *Short Ride In A Fast Machine* – makes this worth a listen.

Shark Week

Animal Planet
Starts 13 August, 9pm

Starting with an hour-long documentary on the great white and why it's attacking more of us, get a nightly fix of shark action for a whole week. Some of the first-hand accounts from victims of the ocean's deadliest jaws might keep you out of the water and safely on the beach. But there's also film from deep water habitats, and insights into how and why sharks hunt with such ruthless efficiency.

The Seahorse Man

Eden
24 August, 9pm

Seahorses are suffering from a loss of habitats in the world's oceans. But charismatic marine biologist Kealan Doyle has a plan. Seahorse Island will be the most ambitious seahorse breeding project to date, based not in the tropics but in Connemara, Ireland. Facing personal, practical and financial challenges, can Doyle make his seahorse ranch a reality?

Wild X Files

Nat Geo
Starts 22 Aug, 8pm

This new season investigates mysteries of the natural world that reveal our planet to be stranger than any alien world. Why do shark attacks peak at full Moon? What caused 5,000 blackbirds to fall dead from the skies one New Year's Eve? And what's stalking the dog walkers of the Cotswolds? Only one of these may be "an over-zealous park keeper with a pocketful of blue plastic bags".

Freaks And Creeps

Nat Geo
Starts 14 Aug, 8pm

We all know the recipe for a wildlife series. One zoologist – Lucy Cooke, tick. Some spectacular locations – Tasmania, Africa, Borneo, tick. And some cute furry animals – ah, there's the rub. It seems Lucy prefers her co-stars weird, ugly and frightening. She loves tarantulas, dung beetles and vultures of course. But a venomous, egg-laying mammal, or a bat that lives in a carnivorous plant? And you thought you worked with some freaks…

Building The Empire State

Nat Geo
14 August, 9pm

"Like performing heart surgery in a phone booth" – that's how building a skyscraper in Manhattan was once described. Nonetheless, 80 years ago the iconic Empire State Building sprang up on New York's skyline at the rate of 4.5 storeys a week, an ambitious feat of engineering even by today's standards. This film looks back at its construction, and at the One World Trade Center now being built on the site of the Twin Towers.

Big, Bigger, Biggest

Channel 5
Starts in July

The series that layers physics, engineering, social history and human stories under an irresistibly cheesy CGI topping is back. This time they're looking at towers, tunnels, trains, ships, canals and prisons. What engineering breakthroughs of the past enable the oil tanker Timofey Guzhenko to break through the Arctic ice today? And how did the Manchester Ship Canal help make the Panama Canal possible? Find out here.

BRAINTRAINING

Pit your wits against these brainteasers by **David J Bodycombe**, question-setter for BBC Four's *Only Connect*

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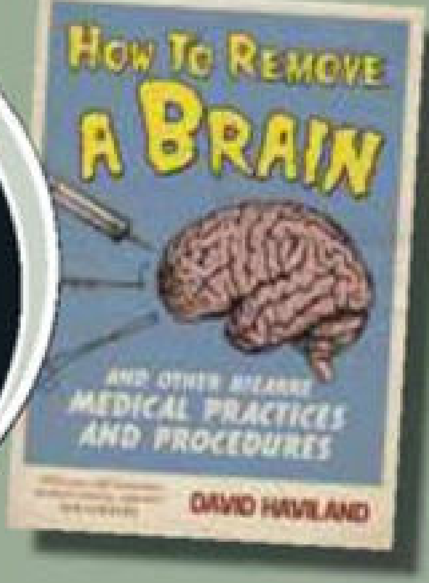
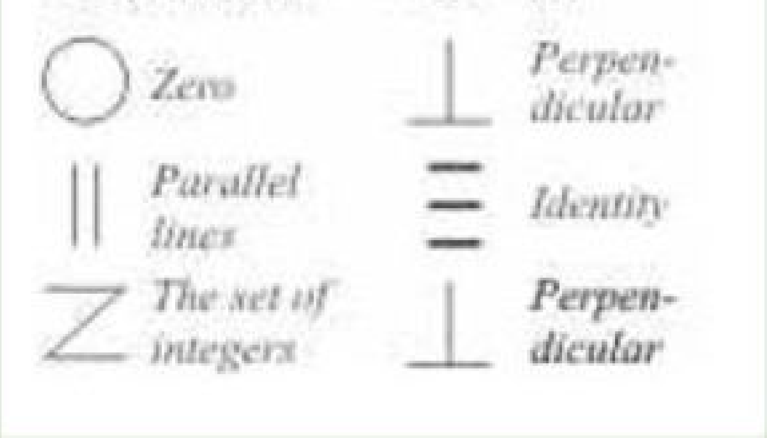


Prize Puzzle

How can all these mathematical symbols be used, with some rearrangement, to form a fraction?

The first five correct entries drawn will win a copy of *How To Remove A Brain* by David Haviland (Summerdale, £7.99). Post your entry, marked 'Prize Puzzle 245', to: *Focus* Magazine, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 23 August 2012. We regret that we cannot accept email entries for this competition.

See bottom of p82 for terms and conditions. Congratulations to Simon Brown (London), Julian Cowley (Worcestershire) and Peter Haworth (Bristol) who all answered June's Prize Puzzle correctly to win *The Sky At Night* by Patrick Moore and Chris North.



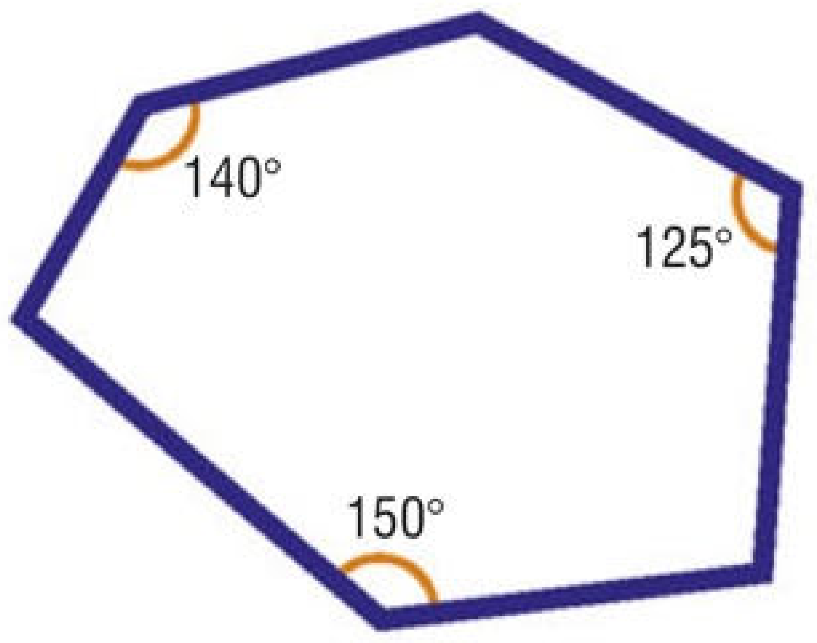
See *sciencefocus.com/winners* for previous winners and solutions

QUESTION 1

What are the traditional rings containing diamond, emerald, amethyst, ruby, emerald, sapphire and tourmaline stones called?

QUESTION 2

What is the total of this shape's internal angles?



QUESTION 3

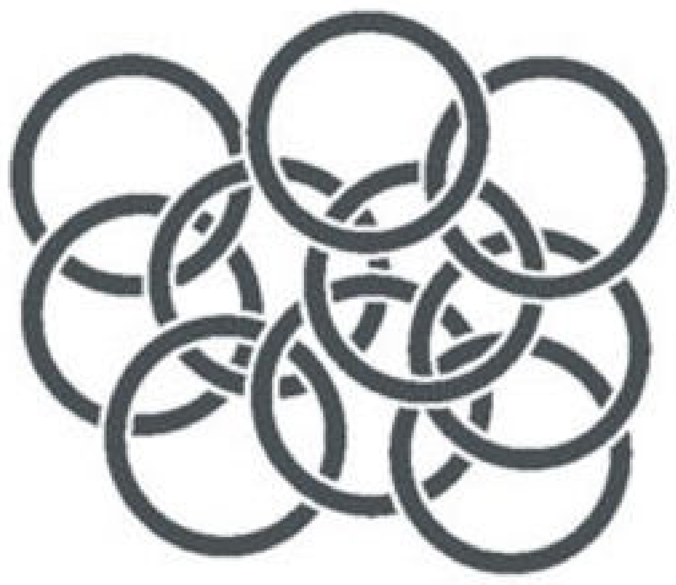
What, appropriately, do you get if you combine these clues: swindle; common household pet; small printer's space; @; charged particle?

QUESTION 4

How could a scientist measure the volume of a large, irregularly-shaped lake efficiently without measuring any depths or distances?

QUESTION 5

Which two of these rings are different from the rest?

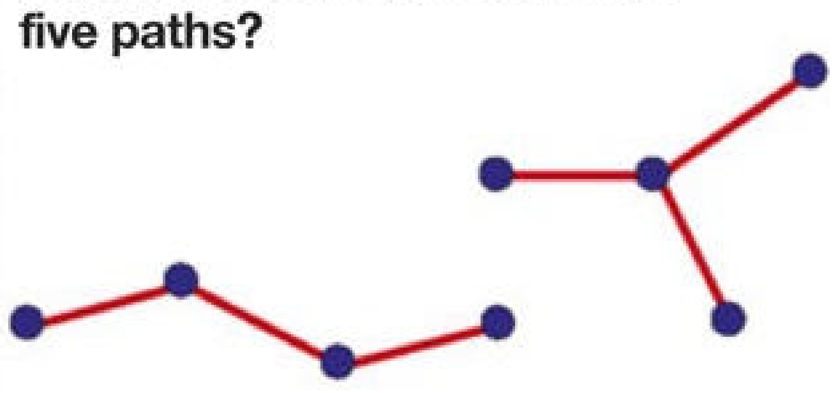


QUESTION 6

During a sale, the price of a microscope was slashed by 50 per cent. When the sales had finished, the price went up 50 per cent to £26.25. What price was it originally?

QUESTION 7

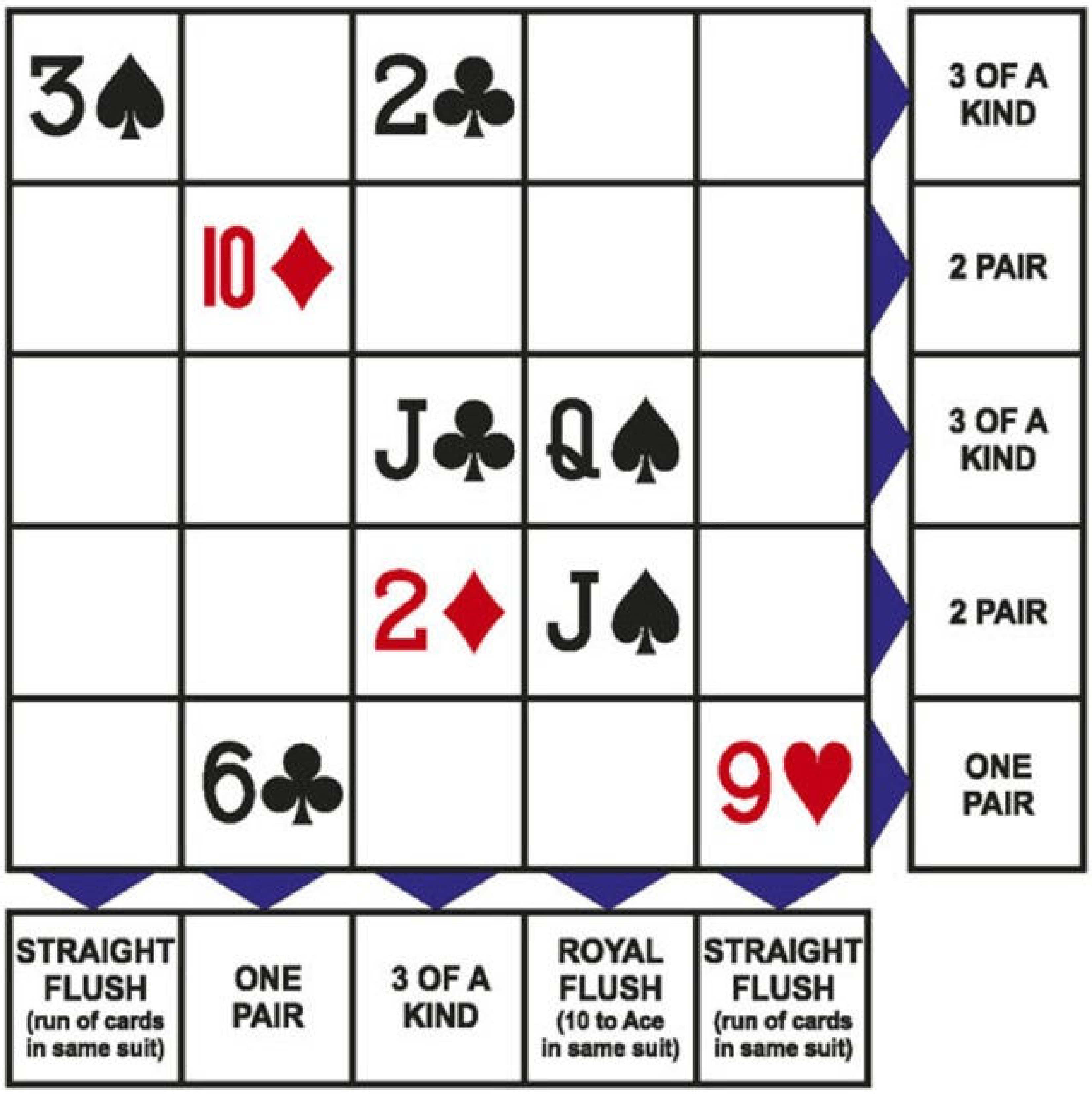
There are only two fundamentally different ways of connecting four points with three paths, as shown.
(a) How many ways of connecting five points with four paths?
(b) What about six points and five paths?



QUESTION 8

Move the listed cards into the grid so that the best possible poker hand in each row and column matches the label shown. The cards are not necessarily in the right order (eg, 5-4-6-7-3 still counts as a 7-high straight).

2♥ 2♠ 4♠ 5♣ 5♠ 6♠ 10♣ 10♥ 10♠ J♦
J♥ Q♥ K♣ K♥ K♠ A♠



3♠		2♣			3 OF A KIND
	10♦				2 PAIR
		J♣	Q♠		3 OF A KIND
		2♦	J♠		2 PAIR
	6♣			9♥	ONE PAIR
STRAIGHT FLUSH (run of cards in same suit)	ONE PAIR	3 OF A KIND	ROYAL FLUSH (10 to Ace in same suit)	STRAIGHT FLUSH (run of cards in same suit)	

Solutions

3♠	K♣	2♣	K♠	K♥
5♠	10♦	5♣	10♠	Q♥
4♠	J♦	J♣	Q♠	J♥
2♠	10♣	2♦	J♠	10♥
6♠	6♣	2♥	A♠	9♥

Q1) Dearest rings (first letter of each stone). Q2) 720 degrees, just like any convex hexagon – regular or irregular. To see why, divide up the area into four triangles. Q3) The answers spell CON-CAT-EN-AT-ION, which means 'joining together'. Q4) Add 1 litre of a 'tracer' liquid. Wait long enough for this to be dispersed evenly. If the average 1 litre sample then contains (eg) 2 parts per million of the tracer, then the lake's volume is 500,000 litres. Q5) The leftmost two are linked together. Q6) $(x/2) + ½(x/2) = 26¼$, so $¾x = 105/4$. Hence, $3x = 105$, so it cost £35. Q7) (a) Three – the same as the two shown but with one end extended, plus a new network in a + shape. (b) Six ways. Q8) See illustration.

Quick Quiz

Test your knowledge of atomic particles

QUESTION 1

1) The word 'atom' is derived from the Greek for what?

a) Indestructible
b) Invisible
c) Indivisible

QUESTION 2

The electron belongs to which of these particle families?

a) Boson
b) Lepton
c) Hadron

QUESTION 3

What is the first name of Professor Higgs, originator of the Higgs boson theory?

a) Paul
b) Peter
c) Percy

QUESTION 4

Which of these is not a type of quark?

a) Charm
b) Strange
c) Magic

QUESTION 5

What 'flavour' of neutrino is produced in the Sun?

a) Electron neutrino
b) Muon neutrino
c) Tau neutrino

QUESTION 6

What is the circumference of the Large Hadron Collider?

a) 7km
b) 27km
c) 47km

QUESTION 7

Which of these is a hypothetical, unconfirmed subatomic particle?

a) The wino
b) The dino
c) The lino

YOU ARE:

0-3 Weakly interacting
4-5 An accelerating proton
6-7 The God particle

Answers: 1c, 2b, 3b, 4c, 5a, 6b, 7a

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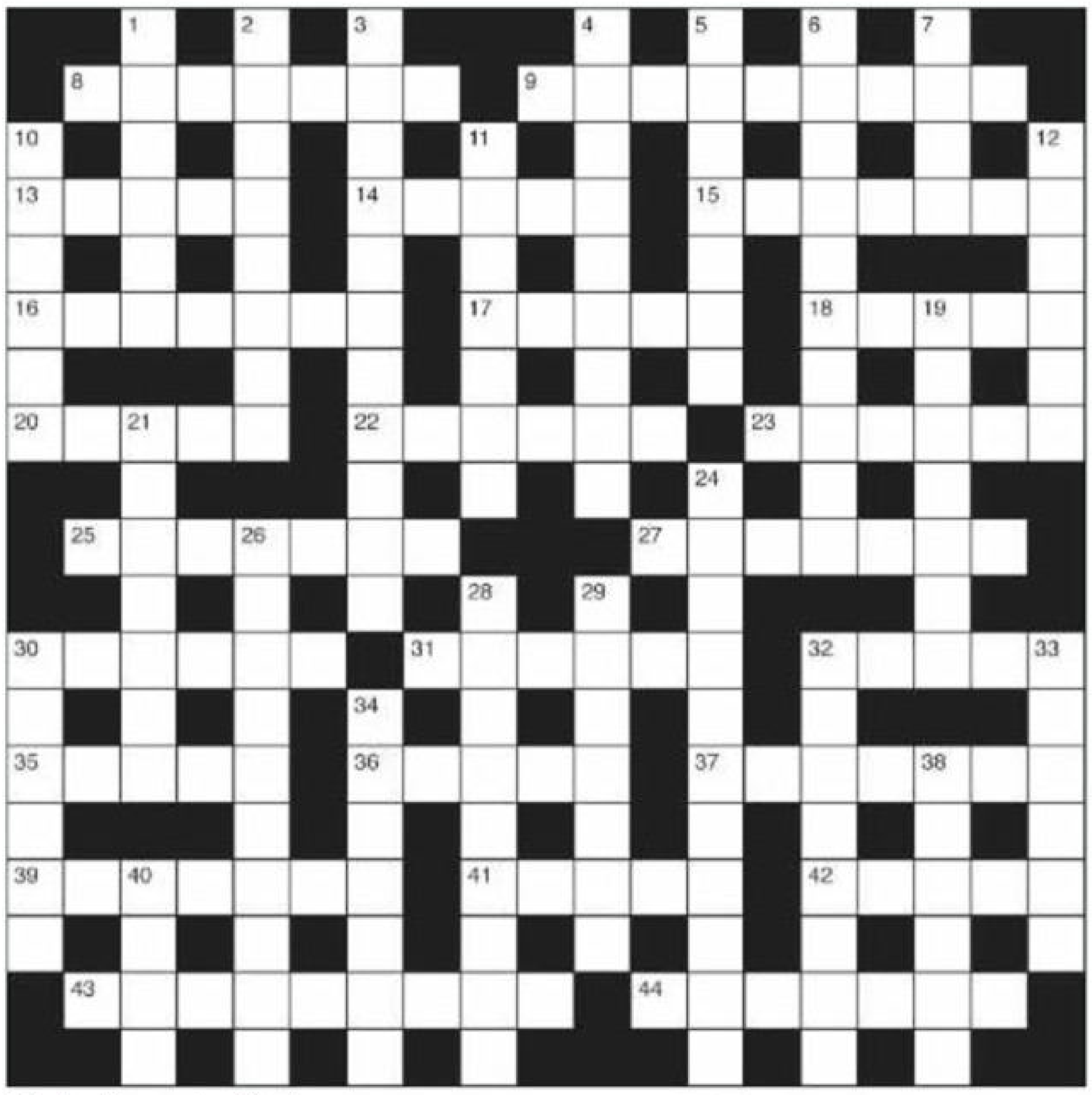
Focus **crossword** Nº 141



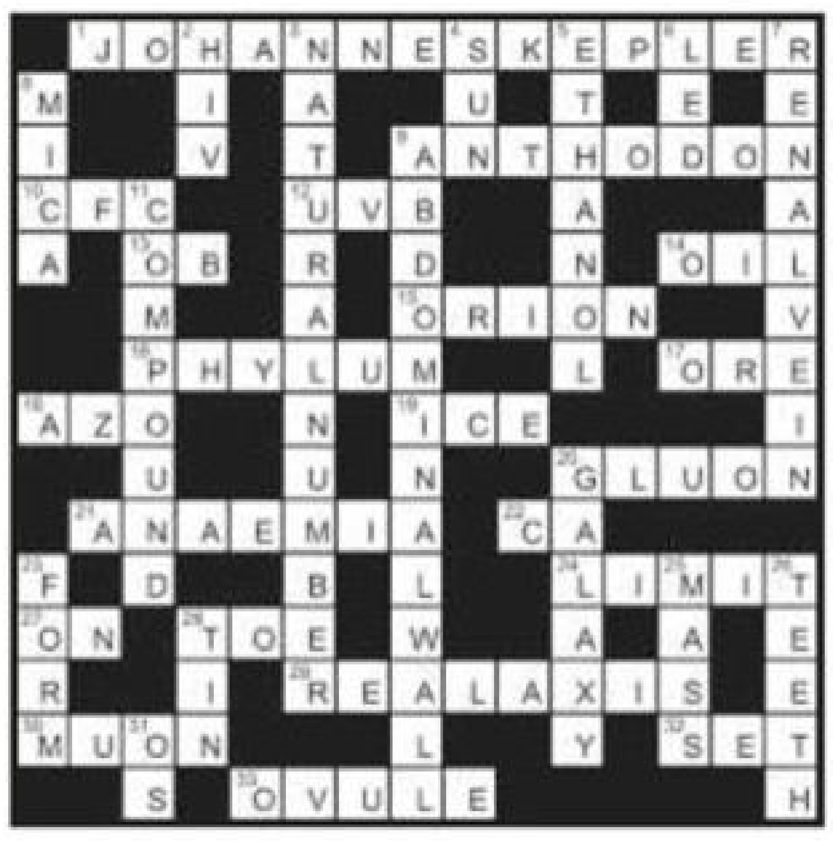
Across

8 Scoundrel has to declare a corpse (7)
9 Right mixture of cure and rest can restore life (9)
13 Information on alien, catlike mammal (5)
14 Oily solution includes an antiseptic (5)
15 Horse running on foot (7)
16 Sprain treated with one painkiller (7)
17 Exercise is able to supply nourishment (5)
18 Alternatively chewed a sphere (5)
20 Rota devised by a vital supplier (5)
22 The rocket, initially, crashed into Neptune's moon (6)
23 Force woman to leave ancient city (6)
25 Incorporated one small gold tooth (7)
27 Sarcastic form of soda (7)
30 Last characters returned and obtained energy cell (6)
31 Lie about stink outside – it's gas (6)
32 Vendetta gets rector to shrink (5)
35 Entrance made with new benefactor (5)
36 Radio station to help acorn transportation (5)
37 Seriousness that's attractive (7)
39 Clay shapes round the edge reveal old science (7)
41 A riot out of proportion (5)
42 Pick-me-up, usually after a gin (5)
43 One mansion built by Catholic, and he can't go out (9)
44 Fertiliser endlessly treating problem (7)

Down

1 I can't deal with pressure at the plant (6)
2 Drug in old Asian country has micro-organisms (8)
3 Formal refusal to reveal planetary angle (11)
4 Right to let force manoeuvre telescope (9)
5 Songbird used as decoration (7)
6 Working environment gets Scrooge in trouble with Frenchman (10)
7 Cost upsetting Briton (4)
10 One South American country has lost unknown lizard (6)
11 Germ-free apes develop twitch (7)
12 Box by the river shows sign of destruction (6)
19 Wife has doctor return a sedative (7)
21 Some radiation in the front, generally (7)
24 Send a goblin home to get some protein (11)
26 Ferret in no other way used to combat virus (10)
28 Lively being from the planet nearest the Sun (9)
29 Torch left in front of rock (7)
30 Some constellations in zone with too much CIA involvement (6)
32 Break RAF truce, badly (8)
33 Without alcohol, diamonds or carbon dioxide (3,3)
34 Tiny warrior made Mary rewrite a book (4,3)
38 At home, neat order is not learned (6)
40 Solid ice cream (4)

Solution to Science Crossword No 1



Win A copy of How To Grow A Planet (BBC, £25.52)

The first five correct solutions drawn will each win a copy of* How To Grow A Planet *(BBC, £25.52). Entries must be received by 5pm on 23 August 2012, when the winners will be drawn at random.

Congratulations to Susan Wilton (Northumberland), David Paylor (Reading), Mrs S Stride (West Sussex), William Bourchier (London) and Stephen Savage who correctly solved June's Science Crossword (No 1) and each receive a copy of *Science In Seconds* by Hazel Muir.

YOUR DETAILS

NAME:

ADDRESS:

POSTCODE: **TEL:**

EMAIL:

Post entries to BBC *Focus* Magazine, August 2012 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to august2012@focuscomps.co.uk by 5pm on 23 August 2012. Entrants must supply their name, address and phone number. By entering, participants agree to be bound by the terms and conditions, printed in full on page 82. Immediate Media, publisher of *Focus*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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All genres welcome

Then, Now & Next
TELEVISION

It was a 20th century invention, but TV is poised to take another leap forward

WORDS: JAMES LLOYD

◀◀ THEN

On 22 August 1932, the BBC began its first experimental TV service, using a system devised by John Logie Baird. The first TV stars performed in front of a camera that consisted of a spinning drum covered with mirrors. A light shone onto these rotating mirrors caused a thin scanning beam to sweep over the subject and reflect back onto an array of light-sensitive photocells. These converted the reflected light into electric pulses, which were then amplified and broadcast using radio waves. At the other end, proud owners of a Baird 'Televisor' could tune into the flickering, 30-line transmissions. Several thousand viewers, or 'lookers-in', witnessed those early TV programmes, which encompassed music, fashion, dance and a performing sea lion. But Baird's mechanical device was soon made obsolete by the development of the cathode ray tube, an all-electronic television. In 1937, Baird's system was dropped in favour of a 'high-definition' 405-line service.

❚❚ NOW

The 'high-definition' TV of the late 1930s pales in comparison to today's HDTV systems. In December 2007, the BBC launched its first HD channel, broadcasting at a resolution of 1,440 x 1,080 pixels – that's roughly 1.6 million pixels per frame. HDTV is a relatively recent development, but even higher resolutions are on the way.

Ultra High Definition TV (UHDTV), also known as Super Hi-Vision, is being pioneered by Japan's public broadcaster NHK. This format boasts a resolution of up to 7,680 x 4,320 – that's over 33 million pixels in total – and in May this year, NHK and Panasonic put a mammoth 145-inch UHDTV display on display at NHK's Tokyo headquarters.

It will be years before this technology arrives in our homes, but you might be lucky enough to see it for yourself this summer. The BBC will be broadcasting the Olympics live to UHDTV-equipped cinemas in London, Bradford and Glasgow – it promises to be the next best thing to being there. To attend a screening, see http://bbc.in/zMoPSS

▶▶ NEXT

Imagine a nature documentary where you can select your own view, or a sci-fi thriller where you can peer round a dark corner. One day, this may be possible thanks to 'integral 3D' technology. 3D-capable TVs have been around for a couple of years, but many people are put off by the prospect of having to wear 3D glasses. So manufacturers have developed 'autostereoscopic' displays that show 3D images without the need for any cumbersome special headgear.

The most ambitious of these technologies is integral 3D, currently being researched by NHK. This uses an array of microlenses covering the screen to display a 3D image that shifts as the viewer moves. To render the multiple perspectives, however, each lens needs hundreds of pixels, meaning that the screen resolutions required to display good quality images are still a long way off.

Nevertheless, integral 3D offers a tantalising glimpse of television's high-tech future – less than a century after Baird's Televisor first wowed its lookers-in. ■

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I am
12:01
I miss you too! Let's meet up sometime!
We're off to Paris next Thursday and I'm going to get a ticket.
12:02
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